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HAND-BOOK
TO ATLAS
OF
HUMAN ANATOMY AND PHYSIOLOGY.

BY
WILLIAM TURNER, M.R.C.S. ENG.,
DEMONSTRATOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH.

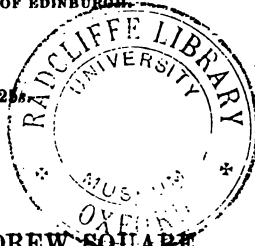
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SELECTED AND ARRANGED UNDER THE SUPERINTENDENCE OF
JOHN GOODSIR, F.R.S.S.L. & E.,
PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH.

Price of Atlas and Hand-Book, 25s.

EDINBURGH:
W. & A. K. JOHNSTON, 4, ST. ANDREW SQUARE,
GEOGRAPHERS AND ENGRAVERS TO THE QUEEN.
LONDON: E. STANFORD, CHARING CROSS; GROOMBRIDGE AND SON,
PATERNOSTER ROW. DUBLIN: M'GLASHAN AND GILL.

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521



ENTERED AT STATIONERS' HALL.

MURRAY AND GIBB, PRINTERS, EDINBURGH.

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P R E F A C E.

As the Anatomical Engravings, to which these pages are the accompanying Hand-Book, constitute an attempt to introduce into a general education a new feature, some few words respecting their nature and object may not be out of place.

A large number of the most distinguished medical authorities of the present day have testified to the advantages to be derived by including some knowledge of the structure and functions of the Human Body under the other elements of a general education.

Many of those who have the management of some of our large schools have also agreed in the propriety of teaching the rudiments of Anatomy and Physiology in those institutions.

With the view of facilitating the teaching and acquiring such information, the present publication has been prepared.

The popularising of anatomical knowledge is, however, a task of considerable difficulty, for, from the very nature of the subject, the various parts figured and described can of necessity only be seen and handled by the professional and scientific student. Drawings, however accurately they may be executed, and descriptions, however clearly they may be written, both fail to give so definite an impression as would be afforded by an

ocular demonstration. This necessarily interferes, to a great extent, with the clear conception by the pupil of the parts that the teacher may be describing.

It would not be possible, in a work of this kind, to enter minutely into the functions, or to describe in detail the different structures and organs, of the human frame. Those desiring such information may obtain it by referring to the various larger works on this subject. It is my intention here only to describe and illustrate the *leading principles* on which the human body is constructed, and it is with this object that the following examples, as more especially fitted for such illustration, have been selected.

The writer must acknowledge his obligations to Professor Goodsir for much valuable advice, given at various times during the preparation of the work. He has also to thank the artists for the care and attention bestowed upon the preparation of the drawings, many of which are original, the rest being selected from various Anatomical Works.

WILLIAM TURNER.

COLLEGE OF EDINBURGH,
August 1857.

HUMAN ANATOMY AND PHYSIOLOGY.

PART FIRST.

CHAPTER I.

INTRODUCTORY.

Anatomy, in its most extended sense, signifies a knowledge of the structure or formation of all living beings.

Physiology treats of the functions that are performed by living beings, and by the different organs composing them.

It is intended in the following pages to explain some of the leading points connected with the Anatomy and Physiology of Man.

The Human Body is divided into three parts—the Head and Neck, Trunk, and Extremities.

The head is the summit of the body; it contains the brain, the organs of sense, and the face, the latter presenting the orifices of the nose and mouth. The neck is the elongated part connecting the head to the trunk; it contains the gullet and windpipe.

The trunk consists of two parts; an upper, called the chest (thorax), containing the heart and lungs—the organs of circulation and respiration; and a lower, called the belly (abdomen), containing the stomach, liver, etc.—the organs of digestion.

The extremities are, as it were, appendages of the trunk, the two upper ones being named the arms, the two lower the legs.

The whole of the outer surface of the body is invested by a *highly sensitive protecting structure, the skin; beneath which is*

placed a layer of fat, varying in its thickness with the stoutness of the individual.

These different parts cover the bones, the organs of support ; the muscles, the organs of motion ; the blood-vessels, the tubes that carry the nutritive fluid ; the nerves, the cords that convey the force that induces sensation and motion ; together with the walls and contents of the cavities of the head, chest, and abdomen.

General Structure of the Body.—The various structures existing in and composing the human body, may be primarily divided into two great classes, Fluids and Solids.

Of the fluids, the most generally diffused is the blood, which is conveyed throughout the entire system along a somewhat complex arrangement of tubes. Another fluid existing also pretty generally, though in much less quantity than the blood, is the lymph.

As the blood flows through different parts of the body, certain fluids are separated from it, which, under the name of secretions, fulfil important purposes in the animal economy. Amongst the most remarkable of these are the bile, urine, sweat, and saliva.

The animal solids present every shade and variety of density and hardness. The teeth and bones are of a dense, firm, ivory-like texture ; the cartilage is of a softer and more elastic nature ; the muscles are still softer and less firm ; whilst those great nervous masses, the brain and spinal cord, may be readily broken down by the fingers. Not merely do the different parts vary greatly in their density, but they present at the same time considerable differences of colour,—every gradation of tint, from the brilliant white appearance of the teeth, through the slightly yellowish colour of bone, to the deep reddish brown hue of the muscles. These variations in the colour are due, to a great extent, though not entirely, to the amount of blood that is contained by the tissue.

Certain elementary structures, closely resembling each other in appearance, may be observed in many of the solid tissues. *The most abundant and generally diffused of these elementary*

particles are the minute bodies called Cells. These are in every instance so extremely small, that they can only be detected by the aid of a powerful microscope. They all present certain characters in common, having more or less of a bladder-like appearance. At some period or other of their existence, they all possess a distinct wall, which separates the contents of one cell from those adjoining it. These contents are generally fluid, which differ considerably in their nature in the cells found in the different tissues; but all the cells agree in this respect, that, together with the fluid contained in them, they possess a small solid particle called a nucleus. The nuclei do not always exist in cells, but are often found lying distinct and separate from them amongst the various tissues.

The cells vary much in shape. Examples of the different kinds are furnished in several of the Plates, as in Plate 4, Fig. 7, the globules of the blood; Plate 5, Fig. 6, ciliated epithelium cells; in Plate 6, Fig. 6 and 9, cells of the stomach and liver; in Plate 7, Fig. 2, nerve-cells.

All the tissues, in their primary state, are probably composed to a great extent of these particles. As they grow older, however, certain changes take place in many of them, which result in the disappearance of the cells, or their metamorphosis into other structures, so that the original cellular nature of the tissue becomes lost or obscured. These changes are especially seen in those tissues in which the functions performed are not very active. In all the structures, however, such as the glands, where the processes are carried on with great activity, the cells are very numerous.

Tissues having more or less of a fibrous character, are also extensively diffused throughout the system. One of the most generally present is the tissue especially called fibrous, figured in Plate 2, Fig. 2, the Ligaments. The yellow or elastic fibre, Plate 4, Fig. 5, the Arteries affords another example. Muscular fibre, Plate 3, Fig. 3, and Nerve fibre, Plate 7, Fig. 2, are also instances of fibrous structures. All these, although possessing a

fibrous character, yet differ, however, materially in their structure from each other. They cannot be regarded either as so elementary in their nature as the cells, and they are probably formed by the elongation and alternation of cells or their nuclei.

Certain membranes, possessing to some extent corresponding characters, are also to be observed in different parts of the body. Of these the most important are the Mucous and Serous membranes.

The mucous membranes are found lining all those cavities of the body which open on to the surface. The best marked of these are the membranes lining the cavities of the mouth and nose. These are prolonged on the one hand down the windpipe into the lungs; and, on the other, down the gullet into the stomach, and along the whole length of the intestinal canal, to its lower extremity. They secrete a small quantity of a viscid tenacious fluid called mucus, which keeps their surfaces continually moist. Along the passages lined by these membranes, at certain intervals, materials proceed to or from the organs to which the passages lead. Thus, air is conveyed to the lungs by the windpipe, and food passes to the stomach by the gullet. The mucus moistening the surface of the membrane protects it from injury during the passage of any substance along it, whilst, at the same time, it greatly facilitates the passage of any solid material.

The serous membranes, on the other hand, do not communicate with the surface. They form, as it were, closed cavities. They are placed within the great cavities of the body, and surround certain of the organs contained therein. They are found wherever an organ, in the performance of its function, has to move in its position. Their surfaces are consequently smooth, and moistened with a small quantity of fluid, in order to facilitate this movement. Of these membranes, the most important are the pleuræ, which invest the lungs; the pericardium, which invests the heart, and the peritoneum, which surrounds the stomach, intestines, and certain other organs contained in the cavity of the *abdomen*.

Closely allied to the serous are the synovial membranes, which surround the ends of the bones that enter into the formation of the joints. The fluid secreted by these membranes lubricates the surfaces which move upon each other.

Chemical Composition of the Body.—Diverse as these parts appear in their colour, texture and other physical properties, yet, when examined by the aid of chemistry, they are found to present many elements in common.

Of the numerous elements which the chemist has detected in the various objects of nature, comparatively only a few appear to be necessary to the formation of the animal body.

Of these the most abundant are the elements, oxygen, hydrogen, nitrogen and carbon, which, from their general diffusion throughout the whole organized world, have been termed the organic elements.

By the organized world is meant all those structures, whether animal or vegetable, which possess or have possessed life.

Certain other elements, and in some instances in considerable quantity, assist in the formation of the animal structures. The most important of these are, amongst the non-metallic elements, sulphur, phosphorus and chlorine; and amongst the metallic elements, potassium, sodium, calcium, magnesium and iron.

By the combination of two or more of these different elements with each other, in varying proportions, several substances are formed, which, from the fact of their composing a great part of many of the animal tissues, have been called the proximate elements of the body.

These may be divided into those that contain nitrogen as an essential constituent, and those in which nitrogen is not present.

Of the nitrogenous proximate elements, fibrine, albumen, caseine, gelatine and chondrine, are the most important. In addition to the nitrogen, these substances contain considerable quantities of carbon, oxygen and hydrogen, and a small proportion of sulphur and phosphorus. Fibrine exists both in the blood and muscles. Albumen also constitutes an essential con-

stituent, not merely of the blood and muscles, but also of most of the animal fluids. Caseine is found in great abundance in the milk, and to a slight extent also in the blood. Gelatine composes a considerable proportion of the bones, and it is also found in certain of the softer tissues, especially the fibrous. Chondrine constitutes the essential constituent of cartilage.

Of the non-nitrogenous proximate elements, the various fatty matters, constituting the fat of the body, are the most remarkable. The most important of these are composed of certain substances, to which the chemist has given the names of stearine, margarine and oleine. The more solid fats, such as suet, being composed to a great extent of stearine; the more liquid or oily fats, consisting essentially of oleine. These different fatty substances all possess the property of forming a soap when digested with alkalis. There are certain other fatty principles, however, which are not capable of being converted into soap. The most important of these is cholestearine, a substance which is found in the bile and in the brain.

Sulphur and phosphorus appear to be elements of great importance in the building up of the animal textures. They are found together in the several nitrogenous proximate principles already described. Sulphur exists also in the hair, nails and cuticle, and, to a small extent, also in some of the other textures. Phosphorus is found, in considerable quantity, in the nervous tissues, especially in the brain. In combination with oxygen as phosphoric acid, this substance assists in the construction of almost all the various tissues composing the animal fabric. This acid is combined with soda in the blood, with potash in the muscles, and with lime and magnesia in the bones and teeth.

Chlorine also exists in appreciable quantity in the different tissues. It is generally combined with the metal sodium, forming the compound with which every one is so familiar,—chloride of sodium, or common salt. There is probably no texture in which a small proportion of this compound cannot be detected. The *manner in which this salt is diffused throughout the body explains*

the desire for salt as an article of food, and the great distress that always supervenes when the system is deprived of it for any length of time.

Iron also exists in small quantities in the great majority of the tissues. Its especial seat, however, is the blood; in the globules of which it forms an essential and considerable constituent. The various elements above described, and a few others, which are much less generally diffused, and of apparently minor importance, are so combined in the animal textures, that they cannot, by the naked eye, or by any ordinary mode of observation, be discovered. The tissues composed of them must be subjected to the action of powerful chemical agents, when, by the application of the appropriate tests, they may each of them be detected.

General Functions.—The functions performed by the tissues may be divided into two great classes :—

1st, The functions of organic or vegetative life.

2d, The functions of animal life.

The first class has derived its name from this circumstance, that the functions composing it are performed by all those beings which possess that mysterious principle called life, whether they be plants or animals. These functions are not necessarily performed to the same extent, or in the same manner, in all the various subdivisions of the organized world. They principally minister to the preservation of life, and are consequently employed in the absorption of nutritive material or food from without; in the circulation of this nutritive material throughout the system; in the assimilation of it to the different textures of the body, so as to assist in their growth and maintenance; and in its purification, especially through the functions of respiration and secretion.

The functions of animal life are performed exclusively by animals. These are especially manifested through the agency of the nervous system, and the various sensory and motor organs connected with it.

The most characteristic animal faculty is consciousness, by

which the creature becomes cognisant of impressions made upon it from without, or of certain changes taking place in its own structures, which it is enabled to comprehend through sensation. Another of these animal faculties is that of voluntary motion, by which the animal can move either its entire body, or parts of it, from one locality to another. In man the functions of animal life greatly preponderate, and exercise a great influence over those of organic life. This is owing to the circumstance, that in him the nervous system is greatly developed, in accordance with the possession of his superior mental attainments.

We will now proceed to consider more in detail the different tissues, and the functions performed by them.

CHAPTER II.

THE SKELETON.

IN order that the form of the body may be properly preserved, its various parts kept in due position, and the different functions required of it efficiently carried on, it is necessary that it should possess a solid frame-work or support. This is given to it by the presence in its interior of a firm, hard material, called Bone. The different bones found in the human body are composed of this material. The name of Skeleton is given to the bones when placed in such a position as they occupy in the living body.

Fig. 1 is a front view of an adult skeleton.

If the eye is cast over it, it will be seen that the bones may be naturally divided into those that occupy the head and neck, those that are found in the trunk, and those that lie in the extremities. Certain of these bones, which bear a great resemblance to each other in shape, and which evidently belong to the same group or *series*, have been classed together under a common name. Thus all

the bones forming the spinal column are called *Vertebræ*. The great majority of the bones, however, possess special and distinguishing names. To some names have been given, which express the locality or position which they occupy in the living body, as bone of the forehead, bone of the thigh, etc. To others names have been given which indicate peculiarities of shape, or some supposed likeness to geometrical figures, or well known objects;—thus there are the cuboid bone, the ploughshare-shaped bone, the boat-shaped bone. These names were applied many hundreds of years ago by the old writers on anatomy; and although in some instances the bones do bear some general resemblance to the objects after which they are called, yet this is often far-fetched and fanciful. We will, in the first instance, name the bones, according to their division into the parts already indicated.

Bones of the Head and Face:—

1. Bone of the Forehead (Frontal bone).
2. Bone of the Side of the Head (Parietal bone).
3. Bone of the Back of the Head (Occipital bone).
4. Bone of the Temple (Temporal bone).
5. Wedge Bone (Sphenoid).
6. Nose Bone (Nasal).
7. Bone lodging the tube down which the tears pass (Lachrymal bone).
8. Cheek Bone (Malar).
9. Ploughshare-shaped Bone (Vomer).
10. Upper Jaw Bone (Superior Maxilla).
11. Lower Jaw Bone (Inferior Maxilla).

In addition to the above-named bones, there are others which enter into the formation of this division of the body. The Sieve bone, or *Ethmoid*, called from its presenting on one surface a number of perforations like a sieve, is, for the most part, so concealed by the other bones, that it cannot be seen in the figure. A small portion, however, appears at the inner wall of the orbit. On the outer wall of each nostril is a bone, which, from being peculiarly turned on itself, is called *Turbinated*; and at the back part of the roof of the mouth are a pair of bones called *Palate*, but these cannot be seen in the figure. The bones of the head

and face are thus very numerous ; many of them are single bones, but the majority are arranged as pairs, one on each side. They number altogether twenty-two bones. The number and complexity of shape of these bones depend upon the subdivision of the skull into certain distinct chambers or cavities, for the reception or transmission of important structures. Several of the bones enter into the formation of more than one of these chambers. The most important and largest of the cavities is that which contains the brain. Its roof and side walls are formed by the bones marked 1, 2, 3, 4, which, together with the wedge and sieve bones, constitute the bones of the skull. Certain smaller cavities opening upon the face are likewise formed partly of these bones, and partly of the bones of the face. Thus—

a Represents the Cavity of the Orbit, in which the Eye is lodged.

b The Cavity of the Nose, divided into two parts by a partition composed in part of the Vomer.

c The Cavity of the Mouth, closed in by the Teeth.

Bones of the Spinal Column or Vertebrae:—The spinal column consists of twenty-six bones, placed one above the other. The two lowest of these bones are, in childhood, composed of several smaller bones, which in the adult become joined together, hence they are termed the false vertebrae (15, 16). The rest are called the true vertebrae. Their name is derived from the Latin verb, *verto*, to turn, because they turn slightly on each other in the various lateral movements of the trunk.

The True Vertebrae are 24 in number : they are divided into three portions:—

12. Vertebrae of the Neck—7 in number.

13. Vertebrae of the Chest—12 in number.

14. Vertebrae of the Loins—5 in number.

(See also Fig. 2.)

The False Vertebrae, consisting in the adult of two bones, are termed Vertebrae of the Pelvis.

15. Sacrum.

16. Coccyx. This is the bone which is considerably elongated in animals possessing a tail.

Fig. 2 is a side view of the spinal column.

The vertebræ are represented as being separated from each other by a small interspace; this is filled up in the living body with an extremely elastic substance, the intervertebral substance, represented in the ligamentous plate. The sides of the 10th, 11th, and 12th vertebræ of the chest, and that of the 1st vertebra of the loins, have been removed in order to expose the canal lodged in the interior of the spinal column, which contains the spinal cord.

Projecting from each of the different vertebræ making up the column are several strong processes of bone; some of these, such as *a* and *c*, have muscles attached to them; others, as *b*, are for the purpose of assisting in uniting each bone to those situated immediately above and below it.

a. a. a. The Transverse processes.

b. b. b. The Articular processes.

c. c. c. The Spinous processes; or spines, from which the name of spinal column is derived. These processes may always be distinctly felt beneath the skin of the back.

d. d. Represents the smooth surface on the transverse processes and bodies of the vertebræ, to which the ribs are connected.

The vertebral column extends the whole length of the trunk. To its upper end the head is attached. All the scientific anatomists of the present day regard the bones of the head as essentially belonging to the same set of bones as those that constitute the spinal column, although they have undergone such modifications, both in shape and arrangement, that, without being attentively studied, this resemblance would not be recognised. That they do belong to the same system, is however indicated by this circumstance, that, together, they constitute the walls of the cerebro-spinal canal, or cavity containing the brain and spinal cord; the greater size of the cranial bones over those of the spine being due to the brain being much larger, although not so long as the spinal cord.

If, instead of viewing the human skeleton in the erect posi-

tion, it is so placed that the skull and spinal column lie horizontally instead of at right angles to the surface on which it moves, the human skeleton is then brought into the same condition as that of any other vertebrate animal. These bones are then seen to constitute an axis or centre, to which the other bones of the skeleton are directly or indirectly connected, and to which they may most conveniently be referred. Thus, to the twelve vertebræ of the chest, on each side are attached twelve bones, the ribs, in number twenty-four. The great majority of the ribs are connected in front to the breast bone, 17. To the ribs, through their attachment to the breast bone, the upper extremities are connected. To the lower end of the spinal column, that is, to the false vertebræ, the lower extremities, through the large haunch bones, 27, are united.

The presence of a vertebral column in all Mammalia, Birds, Reptiles and Fishes, has caused anatomists to class them together under the name of Vertebrata.

Bones of the Chest or Thorax (Fig. 1).

The thorax is made up of a large number of bones. In front is—

17. The Breast Bone (Sternum).

At each side are—

18. The Ribs;

Twelve on each side; connected behind to the vertebræ of the chest; in front, to the sternum, except the two last, whose anterior ends are loose, so that they are called floating ribs. The union of the ribs to the breast bone is effected by means of an elastic substance called gristle or cartilage (*x*).

Bones of the Upper Extremity—

19. Collar Bone (Clavicle).

20. Shoulder Blade (Scapula).

21. Arm Bone (Humerus).

22. Inner Bone of Forearm (Ulna).

23. Outer Bone of Forearm (Radius).

The hand possesses a large number of bones, which may conveniently be divided into three portions :—

- 24. Bones of the Wrist (Carpal bones).
- 25. Bones of the Metacarpus, or Palm.
- 26. Bones of the Fingers (Phalanges).

The bones of the wrist are eight in number. They constitute some of the smallest bones in the skeleton. They are arranged in two rows ; the first row consists of four bones :—

- a. Boat-shaped Bone (Scaphoid).
- b. Half-moon-shaped Bone (Semilunar).
- c. Wedge-shaped Bone (Cuneiform).
- d. Pea-shaped Bone (Pisiform).

The second row also consists of four bones :—

- e. The Trapezium, or larger many-sided bone.
- f. The Trapezoid, or smaller many-sided bone.
- g. The Great Bone (Os Magnum). This is the largest of the bones of the Wrist.
- h. The Hook-shaped Bone (Unciform).

The bones of the Metacarpus are five in number—they lie beneath the skin of the palm of the hand.

The bones of the Fingers are fourteen in number, each finger possessing three, which are named first, second, and third phalanx ; the thumb only possesses two. The numerous bones, and, consequently, the numerous joints in the hand, eminently adapt it for the performance of those various delicate movements of which it is capable.

Bones of the Lower Extremity :—

- 27. Haunch Bone (Innominate).

By the junction of the two haunch bones to the sacrum behind, and by their connection together in front, a bony hoop is formed at the lower part of the trunk. The cavity within this hoop is called the basin or pelvis. Several very important organs, such as the bladder, are contained in it ; the wide bony plates of the haunch bones protecting these organs from external injury.

Connected to the haunch bone, on each side, is—

28. The Thigh Bone (Femur).

Passing down the extremity we find :—

29. Bone forming Knee Pan (Patella).

30. Inner Bone of Leg (Tibia).

31. Outer Bone of Leg (Fibula).

The Foot consists of a large number of bones, which may, like those of the hand, be divided into three portions :—

32. Bones of the Ankle (Tarsus).

33. Bones of the Metatarsus, or instep.

34. Bones of the Toes (Phalanges).

The bones of the Ankle are seven in number ; they are named as follows :—

a. Ankle Bone (Astragalus).

b. Heel Bone (Calcaneum).

c. Boat-shaped Bone (Scaphoid).

d. e. f. Three Wedge-shaped Bones (Cuneiform).

g. Cube-shaped Bone (Cuboid).

The bones of the Metatarsus are five in number.

The bones of the Toes are fourteen in number, each toe possessing three bones, called first, second, and third phalanx, except the great toe, which has only two.

The bones of the foot are arranged in the manner best adapted for affording a considerable surface upon which the weight of the body may fall in the erect posture. For the purpose of communicating to the movements of the body a certain spring and elasticity, these bones have been so adapted to each other that they assume an arched form. If the foot be carefully examined, two distinct arches will be found in it, one extending from the back to the front of the foot—that is, from the heel bone to the toes—which constitute, consequently, the piers of the arch ; the other passes from one side of the foot to the other, hence it is called the transverse arch of the foot. These arches are especially well marked at the inner margin *of the foot or instep*. Owing to the vault of these arches being

composed of several bones, and owing to the joints, or surfaces of connection of the different bones to each other, being covered with an elastic material called cartilage, a considerable amount of elasticity is necessarily communicated to the foot.

Again supposing that the skull and spinal column are placed horizontally, the two pairs of extremities will now be seen to hang pendulous from the sides of the trunk, and to possess quite a different axis from that of the cranio-spinal axis. They are, in fact, superadded structures appended to it for certain specific purposes, especially for those of locomotion. They have been called appendages of the trunk.

The arms of man correspond to the anterior extremities, and the legs to the posterior extremities of other vertebrata. The bones of the upper extremity correspond closely with those of the lower. Thus the clavicle and scapula may be compared with the haunch bone; the upper arm bone with the thigh bone; the bones of the forearm with those of the leg; the radius with the tibia, and the ulna with the fibula; the bones of the wrist with those of the ankle; the metacarpal bones with the metatarsal; the fingers with the toes; the thumb and the great toe being corresponding structures. In contrasting the upper and lower extremities, the palm of the hand should be turned downwards, in order that the thumb may become the innermost digit, and thus correspond in its position to the great toe; for the palm is the surface in the hand which is identical with the sole of the foot, and the back of the hand with the back of the foot.

The determination of the structures which correspond with each other, either in the same animal, or in different animals, constitutes, in the language of anatomists, the principle of Homology.

The number of bones constituting the skeleton varies at different periods of life. In very young children the greater part of the skeleton is formed not of bone, but of a gristly or cartilaginous material. As age advances, the peculiar hardening and

change of structure takes place in it, by which it is converted into bone. In some bones this gradual change may be readily watched. Thus the haunch bone, Fig. 1, 27, originally *ossifies* as three distinct bones, which are connected together by intervening cartilage; gradually, however, the osseous matter is deposited in this cartilage, so that in the adult a single bone is formed. As a general rule, however, it may be stated that there are about two hundred bones in the skeleton.

Shapes of Bones.—In Fig. 1 we may observe that the bones present in different parts of the body different shapes. Thus, those forming the head are flattened out so as to cover a considerable extent of surface, hence they are termed *flat bones*. They serve as a fixed point to which muscles are attached, and, from their peculiar arrangement, they enclose a cavity (the cranial cavity) which contains the brain. These bones are curved in their shape, so that of the two surfaces one is convex and looks outwards, the other is concave and looks inwards. They are united at their margins, and it is interesting to observe the beautiful arrangement adopted for ensuring perfect union of the different bones. Instead of the margins being simply placed in contact with each other, they present an irregular, toothed appearance, the teeth of one bone fitting so closely into the space between the teeth of the bone next to it, that they are separated from each other with the greatest difficulty—the accuracy with which the junction is effected equalling, nay, surpassing, the “dove-tailing” of the most skillful carpenter.

This is shown in Fig. 3.

The close union thus subsisting renders the walls of the cranial cavity perfectly incompressible, so that the highly important and delicate organ, the brain, contained within, is, to a great extent, protected from being injured by blows and concussions, which, when received on the head, would necessarily damage it, were not its case so strong and firm. The *vaulted form* possessed by the skull serves also to diminish the

force of any blow that might be received upon its outer surface.

In the extremities the more important bones are rounded and elongated, and thus give to the limbs the length necessary for the proper performance of their various duties. They are called *long bones*.

If the upper and lower extremities are compared, it will be found that the arms are shorter than the legs, owing to the bones in the former being shorter than those in the latter. The bones at the upper part of a limb will be found to be longer than those at the lower part.

A long bone may be divided into three portions, a centre or shaft, and two extremities. The shaft makes up the greater part of the length of the bone; it is narrowest at the middle, but as it extends to either extremity, it gradually widens, so that the ends are the widest parts. This enlargement serves to increase the size of the surfaces for the joints, which are placed at the ends of the bones, and thus it increases the amount of support at those points. The shaft commonly approaches in its shape to that of a cylinder, although it is never a perfect one. The muscles that move the limbs are connected to these bones.

The bones met with in the spinal column, the wrist, and the ankle, are called *short bones*. They are placed in those parts where considerable strength is necessary, without any very great amount of movement being required.

Markings on Bones.—If the outer surfaces of most of the bones are examined, they will be found to present, at various points, rough prominent ridges or elevations, which have received different names in different parts of the body. The prominences situated at the upper end of the thigh bone are called the Trochanters (Fig. 1, *d.d.*), those at the upper end of the arm bone the Tuberosities (*e.e.*) Other processes, longer and more prominent than the above, are named Spines. They are the best marked in the vertebral column (Fig. 2, *c. c. c.*) The different

prominences thus named serve as points of attachment for various muscles, the size and thickness of these eminences being always proportionate to the size and strength of the muscles of the individual.

Bones also possess other prominences, but these are found at the extremities, where one bone joins a neighbouring bone; these are termed the articular eminences or processes. The following names have been given to some of these elevations: the rounded upper ends of the thigh and arm bones are called Heads (Fig. 1, *f.f.*); the constricted part connecting the head to the shaft, the Neck; the expanded lower ends of the same bones, Condyles (*g.g.g.*); the processes formed at the lower end of the two bones of the leg are called Malleoli (*h.h.*)

The part of the adjoining bone that comes in contact with these articular elevations commonly presents an excavation or hollow, to which the elevation is to a great extent adapted, the depth of the hollow varying in different instances. Thus the head of the thigh bone is received into a deep pit in the haunch bone, called Acetabulum (*i*); the head of the arm bone into a much shallower pit in the shoulder-blade (*j*.)

By means of this arrangement a perfect adaptation of the ends of the bones is attained, so as to admit of great accuracy of movement between them.

Again, on most bones, small holes, grooves and depressions may be seen, which are for the purpose of lodging or transmitting either tendons, nerves, or blood-vessels. Thus the groove on the front of the arm bone (*k*) lodges the tendon of that muscle (biceps) that bends the forearm. The small holes seen in many of the bones of the face (*l. l.*) transmit nerves and blood-vessels. The small holes seen on the front of the bones of the forearm transmit small blood-vessels into the interior of the bone (*m. m.*)

✓ **Naked Eye Structure of Bone.**—If a section is made through a long bone in a vertical direction, the interior of the bone will be exposed. In Fig. 4 the thigh bone has been so treated. The

interior of the bone is then found to be hollow in the part corresponding to the shaft, a well-marked canal extending through this portion of the bone, but not reaching to the extremities. The canal is termed the Medullary Canal, and it contains a soft, yellowish, oily fluid, the Marrow. The extremities of the bone, instead of possessing a canal, are observed to contain an immense number of small plates of bone, interlacing with each other, so as to form a very fine and beautiful network. These plates possess a more or less perpendicular direction. Between the plates, small spaces or cancelli are seen, from which circumstance the bone is here called cancellated or spongy. The spaces contain marrow.

The whole of the exterior of the bone is composed of a dense, hard, firm and compact layer, called the compact tissue, upon which the strength and hardness of the outer surface of the bone depend. This is considerably thicker along the shaft of the bone than at the extremities.

The entire arrangement of the osseous tissue in a long bone is for the purpose of combining those two important conditions, strength and lightness. The canal in the centre of the shaft, filled as it is in the recent state with marrow, causes the bone to be much less heavy than if it were solid, whilst at the same time it is proportioned to the duties it is called upon to perform. The peculiar cancellated structure of the extremities of the bone permits of a greatly increased size of this part, where an extensive surface is required for the purpose of forming the joints. The perpendicular arrangement of the small plates in this spongy structure eminently adapt it for transmitting weight in the perpendicular direction, whilst, from the intervening spaces containing marrow, the bone is not increased in weight, although its surface is greatly augmented. Certain bones, such as the thigh bones, which are not quite straight, but slightly curved in their direction, have running along their concavities well marked bony ridges, which contribute greatly to the strength of the shaft.

A flat bone, if sawn across, will be found to consist of two layers of compact tissue, separated by a layer of cancellous tissue, containing the marrow. The flat bones are seen to the greatest advantage in the bones of the skull. The two layers are here called the two tables of the skull, the inner table being much thinner and more brittle than the outer. The intervening narrow space is called the Diploë. In certain parts of some of the flat bones, more particularly in the frontal bone, the two compact layers are separated to a much greater extent, so as to leave a considerable space between them, which communicates with the cavity of the nose, and contains air. The anterior layer of the bone is pushed forwards, so as to produce a well-marked elevation overhanging the orbit. The elevation so produced is represented at *n*, Fig. 1, the space between the bones being seen in Figs. 5 and 16, Plate 8, Organs of Sense. The cavity is called the Frontal Sinus. In the heads of children this sinus does not exist, so that the forehead is almost flat, and destitute of eminences. At the period of youth it begins to form, and it goes on increasing up to the age of manhood—in some individuals being much more prominent than in others. It communicates to the countenance a firm and decided expression.

A short bone consists in its interior of spongy cancellous tissue, the exterior being formed of compact tissue, so that a short bone is constructed like the extremity of a long bone.

Microscopic Structure.—If the outer surface of a bone is examined, it will be observed to be pierced by an immense number of minute holes. Now, if a very thin section of the bone is made in a longitudinal direction, and this section placed under the microscope so as to be highly magnified, the minute holes upon the surface of the bone will be found to be the orifices of a great many minute canals, which pass in a longitudinal direction through the compact tissue of the bone. The canals communicate by cross branches. The appearance thus described is represented in Fig. 5.

a. Haversian Canal.**b. Vessel in the interior of the Canal.**

The canals were first discovered by an anatomist called **Havers**, so that they are named after him the **Haversian canals**. Each of these canals contains a very small blood-vessel, their use being to convey into the interior of the compact tissue a number of fine blood-vessels, in order that the hard and firm part of the bone may have a proper quantity of blood passing to it. Every bone is surrounded (except at the part that, with an adjacent bone, forms a joint) by a strong membrane called the **Periosteum**, and in this membrane the vessels passing to the compact tissue of the bone ramify and break up into branches sufficiently small to permit them to enter the minute orifices of the **Haversian canals** upon the outer surface of the bone.

It will be seen, however, from the figure, that surrounding each **Haversian canal** is a portion of compact tissue, into which the blood-vessels do not pass, so that no blood is directly conveyed to it. A most beautiful arrangement, however, is found, by means of which the blood, or at least those parts of it that contain the proper materials for the nutrition of the bone, can pass into this compact tissue, in order that its life may be preserved, and that it may continue in perfect health. This is perhaps more clearly represented in Fig. 6 than in Fig. 5.

Fig. 6 is a thin slice of bone made in the transverse direction, and magnified about the same number of times as Fig. 5. *a.* Represents the cut orifice of one of the **Haversian canals**, containing a blood-vessel. Surrounding this, the bone is arranged in a series of layers—this arrangement being due to the presence, at nearly regular intervals, of a number of dark spots called **lacunæ** (*b.*); which are, in fact, spaces or cavities in the interior of the bone. It will be observed that from the **lacunæ** an immense number of black lines are proceeding—the lines are owing to the presence of very minute canals, called **canaliculi** (*c.*), which pass from the **lacunæ** in every direction, so as to connect the different **lacunæ** to each other; those from the

innermost set of lacunæ passing to the Haversian canal, so as to open into it. Now, from the blood-vessel lying in the Haversian canal a fluid necessary for the nourishment of the bone is poured out. This passes through the canaliculi into the set of lacunæ nearest the canal, and then by means of the other canaliculi it is conveyed to the rest of the lacunæ. By this means the whole of the compact tissue is freely supplied with blood.

The compact tissue of the bone may thus be regarded as consisting of an immense number of Haversian canals, surrounded by lacunæ and canaliculi. Each canal, with its lacunæ and canaliculi, is named an Haversian system, the canal in every instance being considered as the centre of the system.

Chemical Composition.—Bone is found to be composed of two entirely different materials, one being an animal substance called gelatine, the other consisting of earthy matter, chiefly the phosphate of lime. From the great amount of this salt of lime in the bones, it is called bone earth. That such is the composition of bone may be readily shown by two simple experiments. Take a piece of bone and put it in the fire, it gradually becomes black from the charring of the animal matter; if the heat is continued, all the animal matter is burnt away, the earthy part alone being left, of a white colour, retaining the original shape of the bone, but readily crumbling or breaking down. Again, take another piece of bone, and place it in dilute muriatic acid, all the earthy matter is gradually dissolved out, leaving only the animal matter or gelatine, which, although soft, flexible, and easily cut, yet retains the original shape of the bone. If this is boiled with water it is converted into glue. The quantity of earthy matter is greater in old than in young bones, so that the bones of old persons are much more brittle than those of the young. Children, whilst playing, are continually falling down, sometimes even from considerable heights, without, in the majority of instances, breaking or otherwise injuring their bones. This is owing to their much greater softness, which allows them *to bend and yield*. With the aged, however, a much shorter

fall is extremely liable to occasion fracture, owing to the superior brittleness of their bones.

Uses of the Skeleton.—The skeleton is for the purpose of giving mechanical support to the body. This it is enabled to do by its firmness and rigidity. It also fulfils the important object of protecting certain of the delicate and important organs of the body. In man and other vertebrata this is especially the case with the brain and spinal cord, which are contained in a distinct cavity and canal in the interior of the skull and spinal column. The viscera, situated in the cavities of the chest and abdomen, are also, to a greater or less extent, protected by the bones entering into the formation of the walls of those cavities. The different bones also give a certain shape to the parts of the body in which they are situated; the length of an extremity being proportioned to the length of the bones contained in it. The skeleton also affords a firm attachment to the muscles, which move the body as a whole, or the parts of the body upon each other. For the purpose of fulfilling these various functions, it is differently arranged in different animals. In all vertebrata it forms the central or axial part of the framework—the skin, muscles, and great majority of the viscera and other structures lying outside it. Hence in them it is called an endo-skeleton, for it is within the body. In invertebrate animals the skeleton, when it exists, is generally placed on the exterior of the animal, which it invests, either partially or entirely, as a sort of case, all the soft structures being contained within it. In them it is called an exo-skeleton, for it lies on the outside of the body. The crab or lobster furnish examples. Certain vertebrata, however, such as the armadillo, not only possess an internal, axial, endo-skeleton, but they also have upon their exterior certain osseous structures which constitute an external or exo-skeleton.

CHAPTER III.

JOINTS AND LIGAMENTS.

In the last chapter the names of the bones, their position in the body, their chief markings, their structure and chemical composition and uses, were explained. In the present one, the manner in which the bones are connected together, so as to form joints, will be considered.

A Joint or Articulation signifies the union or joining together of two bones.

This junction is principally effected by means of strong bands passing between the adjacent parts of those bones that are placed in contact with each other.

These bands are called Ligaments, the word being derived from a Latin verb, signifying to bind.

Fig. 1 is a front view of an adult skeleton, representing the principal ligaments that connect the different bones to each other, so as to assist in forming the most important of the joints in the human body.

Commencing with the Head, we shall find that its bones, owing to the peculiar manner in which they dove-tail with each other, do not require the aid of ligaments to bind them together. This is represented and described in Plate 1, and Chapter 2, the Bones. There are only two joints in the head that possess ligaments. These are the joints that connect the lower jaw, at its extremities, to the temporal bones. This jaw is the only bone of the head that requires to perform any movement. Whenever the mouth is opened, the lower jaw is depressed, and when closed, this bone is elevated; no change taking place in the position of *the upper jaw, which is fixed and immoveable.* This alternating

depression and elevation of the jaw occurring during the performance of various essential operations of the economy, especially in mastication, where the food, pressed between the teeth, is reduced to a pulp by the movement of the lower jaw upon the upper.

The different bones of the Spinal Column are connected together by numerous ligaments and other structures passing between various parts of their surfaces and bony projections. These are so arranged, that whilst they effectually keep the bones in contact with each other, yet they allow a small amount of movement to take place between them. Although no two vertebræ can move to any great extent upon each other, yet the whole spinal column possesses considerable mobility, in order that it may adapt itself to the various positions of the body. In Fig. 1 only the ligament *b*, which connects the front surfaces of the bodies of the vertebræ, is represented, together with some few fibres passing between their transverse processes. Certain of the other structures will be described further on.

Turning now to the Thorax, we observe, that the numerous bones assisting in the formation of the walls of this most important cavity are connected together by a very simple arrangement of ligaments. Thus the ribs are jointed behind to the vertebræ of the chest by strong bands, *c*, which extend from the head of each rib to the bodies of the two vertebræ to which the rib is attached. Other bands also, *d*, connect a tubercular projection at the back of the rib to the transverse process of an adjoining vertebra. In front, the great majority of the ribs are connected, through their cartilages, to the breast bone, numerous fibres, as at *a*, extending between them.

Owing to the various joints existing between the ribs and the spine at one extremity, and the ribs and the breast bone at the other, together with its numerous cartilages, the walls of the thorax possess considerable elasticity. This property is of paramount importance, for it not only protects the essential organs

contained in its cavity from injury, but it also assists most materially in the process of breathing or respiration. Its protecting influence is shown in all those cases where blows are received on the chest, especially over the breast bone. Its elastic construction enables it to yield before the force that strikes it. If it were rigid, and the blow severe, some one or other of the ribs would necessarily be broken, and driven in upon the heart or lungs, so as to occasion considerable injury to them.

The manner in which the ribs are connected at their two extremities enables them to rise and fall during the process of inspiration and expiration; but this will be more fully considered hereafter.

The Upper Extremities appear to be only somewhat loosely connected to the bones of the chest, only one joint existing between them. This is found at the inner end of the collar bone, which is jointed to the upper extremity of the breast bone—a certain amount of movement between them being permitted at this articulation.

By its other extremity the collar bone is jointed to the shoulder-blade. This large flat bone lies upon the back of the upper ribs. It is not connected to them at all by ligaments, but several strong muscles attach it both to the ribs and the spinal column. By these muscles it is retained in its proper position. It possesses, however, a considerable extent of movement, which may be readily ascertained by raising the arm so as to touch the back of the head with the hand, when the shoulder-blade undergoes a sort of rotation, that part to which the upper arm bone is connected being considerably elevated.

The humerus, or bone of the upper arm, is connected by one extremity to the shoulder-blade, forming the shoulder-joint. By the lower end it is connected to the bones of the fore-arm, forming the elbow-joint.

The two bones of the fore-arm are articulated together at each extremity, and passing between them is a strong membrane, *h,* which fills up the space existing between those bones in the osseous

skeleton. These bones are connected to those of the wrist, forming the wrist-joint. The numerous bones of the wrist are connected together by ligaments passing between their surfaces both in front and behind. Similar ligaments also connect these bones with those of the hand. The phalanges of the fingers are united by bands, *o*, extending between the sides of their contiguous surfaces.

The Lower Extremities are connected by the haunch bones to the lower end of the spinal column; strong bands, *e*, attaching them to the vertebræ of the loins, whilst equally strong ligaments, *f*, connect them to the false vertebræ. The two large apertures which exist in the skeleton, at the front of these bones, being filled up by a strong membrane, *k*; a sufficient opening, however, being left for the transmission of a nerve and blood-vessels.

The thigh bones are connected by their upper ends to the haunch bones, forming the hip-joints; whilst, by their opposite extremities, they are articulated to the tibia, or inner bone of the leg, to form the knee-joints; the *Rotula patella* or knee-pan enters materially into the construction of this joint. It is placed in front of it, and protects that part, which would otherwise be exposed to injury. This is especially seen when the knee is bent; for now this bone lies completely in front of the joint, so that, as in the act of kneeling, it is the part that touches the ground, and upon it, consequently, the body rests.

The two bones of the leg are connected together at their two extremities, and passing between their shafts, as in the corresponding bones of the fore-arm, is a strong membrane. These membranes, both in the arm and leg, are perforated here and there by small openings, to allow the passage of blood-vessels from one surface of the limb to the other. The bones of the ankle are connected to those of the leg, forming the ankle-joint. They are also connected to each other by strong ligaments, extending between their upper and lower surfaces. In front they are attached to *the bones of the instep*, and these, together with the *phalanges*

of the toes, are joined by ligaments, *o*, similar to those found in the fingers.

Kinds of Joints.—The different articulations in the body may be primarily divided into two great classes—the immoveable and the moveable. Each of these classes, again, admits of certain subdivisions.

The most important of the subdivisions of the immoveable are the following:—*1st*, The peculiar mode of junction of the cranial bones to each other, already explained, and technically called a suture. *2dly*, The nature of the connection between the teeth and the jaw-bones, into which they are inserted; every tooth possessing one or more fangs, which fit into sockets or alveoli in the jaw, so that each tooth is firmly impacted in its place. A comparison has been drawn between this kind of joint and the mode in which a nail fits into the piece of wood into which it has been driven.

The moveable joints are by far the most numerous, and, at the same time, the most interesting, owing to the number of movements many of them are capable of, and the importance of these in the general economy of the body. These joints are found both in the extremities and trunk, as in the shoulder, elbow, wrist, fingers, hip, knee, ankle, toes, vertebral column, ribs, lower jaw, etc. All the moveable joints possess certain structures, which are common to them, so that, before proceeding to the consideration of the different kinds of these joints, it will be necessary to examine into the structures that enter into their formation.

Structure of Moveable Joints.—The structures that assist in forming one of these joints may be classified as follows:—

1st, The contiguous surfaces of the two bones, called the Articular Surfaces.

2d, The cartilage covering the articular surfaces of the bones, the Articular Cartilage.

3d, The bands that connect the two bones, the Ligaments.

4th, The smooth membrane that facilitates the movement between the surfaces, the Synovial Membrane.

Of the articular surfaces, it may be stated that, for the most part, one presents a hollow or depression, into which an elevation on the other surface fits—the depth of the hollow and the prominence of the elevation varying in different instances. There are cases, however, in which two nearly flat surfaces move upon each other, as in the articular processes of some of the vertebræ;—these must be regarded as exceptions to the general rule.

In all these joints the ends of each of the contiguous bones, instead of directly touching each other, are covered with a smooth layer of cartilage, called *articular cartilage*. If there had been direct contact between the ends of the bones, so great would have been the friction from the comparative roughness of their articular surfaces, that the free and smooth motion of the joint would have been considerably impaired; there would have been a tendency also to the wearing away of the ends of the bones. The intervention of these cartilages, from their smoothness and high polish, prevents such injurious consequences; at the same time, the high degree of pliability and elasticity possessed by the cartilage enables it to yield when pressure is applied, and when this is removed, to return to its original state.

The elastic properties of this cartilage prove of especial value in all those cases where a considerable shock is communicated to the frame, as in jumping from a height. The various cartilaginous plates interposed between the different articular surfaces of the bones, in the numerous joints of the lower extremity, all slightly yield before the pressure, so that before the shock reaches the trunk, its force is very much broken, and no injury is occasioned to the important organs contained in the various cavities. An exactly similar effect is produced by the cartilage in the joints of the upper extremities when the hand strikes a violent blow at any hard or firm object.

The ligaments are formed of that description of tissue called fibrous.

Fig. 2 presents an example (highly magnified).

This tissue is composed of an immense number of very fine threads or fibres, collected together in the form of bundles, many of which are parallel to each other, but others cross in various directions, so as to interlace together. The fibres are not straight, but undulating in their outline, so that each of the bundles has a wavy aspect. From the closeness of the texture of this tissue, and from the manner in which the bundles of fibres interlace, it possesses great strength; it is also perfectly non-elastic,—properties which are essential to ligaments, when it is considered what an absolute necessity there is for the bones to be retained closely in contact. At the same time, the tissue possesses considerable flexibility, which enables the ligaments to accommodate themselves to the varied movements of the joints.

Ligaments may be divided into two great classes:—

1st, Those that present more or less the appearance of bundles, hence called *fasciculated*. These have their margins comparatively well defined. Examples may be seen at the elbow-joint (*m.*), knee joint (*n.*), and joints of fingers and toes (*o.*)

2d, Those that present more the appearance of bags or capsules, so that they completely invest the articular surfaces of the contiguous bones. They are called *membranous* or *capsular* ligaments. Examples are furnished by the hip-joint (*p.*), and shoulder-joint (*q.*)

When the interior of a joint is exposed by cutting through the ligaments that invest it, the articular cartilage will then be seen through the thin transparent synovial membrane which covers it.

This membrane is perfectly smooth and transparent, so that the structure of the parts upon which it is placed is seen beneath it. It lines the inner surface of the ligaments, and at the point where these are connected to the bones, it passes from them to the bones, and then over the articular cartilages, so that all the *parts in the interior* of a joint are covered by this membrane, viz.,

the surfaces of the articular cartilages of both bones and the inner surface of the ligaments ; perfect smoothness is thus given to all those parts that touch each other during the movements of the joint.

Still further to diminish the possibility of any injury resulting from the undue friction of the opposing moving surfaces, there exudes into the interior of the joint a viscid oil-like fluid, which lubricates the different parts, and facilitates their motion ; this is called *synovia* or *synovial* fluid. This fluid corresponds in its use to that of the grease applied around the axle of a wheel.

Divisions of the Moveable Joint.—The two chief varieties of the moveable joint are the ball and socket and the hinge.

The best examples of the Ball and Socket are seen in the hip and shoulder joints : the hip is the more perfect of the two, because the cavity into which the globular head of the thigh bone is received is deeper than the cavity that receives the head of the arm bone. In both joints, when fresh, the hollow or socket is deeper than when the dry bones merely are examined, for there is attached to the margin of the hollow a fibrous ring, which, by projecting outwards for some distance, adds considerably to its depth. This embraces the heads of the bones, and assists greatly in keeping them in their position.

In Fig. 1, *q.* and *p.* represent the outer surfaces of the shoulder and hip joints.

The ligament that especially characterizes this form of joint is the membranous or capsular. It completely surrounds the articular surfaces of the bones, enclosing them, as it were, in a bag. It is connected by one extremity to the outer surface of the socket, whilst by the other it firmly embraces the constricted part, or neck of that bone on which the head is situated. This kind of ligament allows great extent of movement to take place in the joint, the ball or head of the long bone being permitted to roll about in every direction. The ball and socket joint may be very fully illustrated by examining the *hip-joint*.

Fig. 3 represents a vertical section of the right hip-joint, to show its internal structure.

- a. Articular Cartilage.
- b. Synovial Membrane.
- c. Capsular Ligament.

The synovial membrane may here be traced lining the inner surface of the ligament, and covering the articular cartilage. In this joint the capsular ligament is not the only agent which retains the bones in their proper position, for the fibrous ring, before described as deepening the socket, closely clasps the articular end of the thigh bone, and thus materially assists in retaining the articular surfaces closely together. The action of this fibrous ring has been compared by some anatomists to that of the common leather sucker employed by boys for raising stones or other weights from the ground. It so closely embraces the thigh bone that neither air nor fluid are permitted to lie between the articular surfaces. Hence the pressure of the atmosphere acting upon the exterior of the thigh, forces the ball into the socket, and keeps it there.

In the interior of the joint is a strong band of fibres called the interarticular or suspensory ligament (*d.*) This is connected by its upper end to a depression a little above the centre of the head of the thigh bone, by its lower end to the lower margin of the great hollow (acetabulum) in the haunch bone, which receives that head.

When a person is standing erect, or with the body slightly bent, a portion of the weight of the trunk is borne directly by the heads of both thigh bones, or of one thigh bone, according as he stands upon one or both legs, owing to the direct pressure of the acetabula upon the heads of those bones. Now, as the end of this ligament that is connected to the lower margin of the acetabulum is much lower than the end connected to the thigh bone, it of necessity suspends that portion of the weight of the body *which is thrown upon it.*

The effect of this is, to distribute over the head of the thigh bone that weight which, supposing the suspensory ligament had not been present, would have been sustained by that portion merely which is in direct contact with the upper part of the acetabulum.

The hip and shoulder joints possess very extensive movements. Of the two the hip is the least moveable, because upon these joints the whole weight of the body is thrown in the act of standing, so that, having to bear at times considerable pressure, they are required to be of a deeper and firmer construction than the shoulder. Hence, in them we find the bones much larger, the sockets for the reception of the heads much deeper, and the connecting ligaments much more tense and strong. The shoulder, on the other hand, in order that free play may be given to the arms, has a shallow socket, and a capsular ligament, which is much more lax than the corresponding structure in the hip.

The Hinge Joint has its best representative in the elbow. The knee-joint and the joints of the fingers and toes also present examples of it.

The kind of ligament that more especially characterizes this form of joint is the lateral ligament; so that in all hinge joints strong ligaments may be found on each side. These vary slightly in their shape, some being flat, others rounded; but they all agree in this respect, that they possess great strength. They are connected by their extremities to projections at the sides of the ends of the bones, which they bind together. It is essential to the proper working of the hinge, that the surfaces should move backwards and forwards upon each other, without any lateral displacement taking place. This is attained by the mode of connection of the strong lateral ligaments. The knee-joint, from its great size, possesses very well marked lateral ligaments.

Fig. 1 (*m.*) gives the external appearance of the elbow-joint.

Fig. 4 exhibits the appearance of the interior when the ligament *in front is cut across.*

a. Articular Cartilage.

b. Synovial Membrane.

Although the ends of three bones,

h. Humerus,

u. Ulna,

r. Radius,

are seen, yet it is only between two of them, the humerus and ulna, that the proper movements of the hinge are performed; these movements are forwards, termed flexion, and backwards, termed extension. The accuracy of these movements is insured by the presence of a pulley-like surface on the humerus at *a*, to which a ridge on the articular surface of the ulna closely corresponds, fitting into it, and moving readily in it in the backward and forward action of the joint.

The radius, from its close connection to the ulna, moves backwards and forwards along with it, yet it cannot be said to form an essential part of the hinge. It possesses, however, a very beautiful movement of its own upon the ulna, for its head is closely confined within a ring, represented in Fig. 5 (*a.*), formed partly of a smooth concave surface on the outer side of the ulna, and partly of a strong annular ligament connected to the ends of this surface: within this ring the head of the radius rolls.

The movement between these bones is effected when the hand, placed on a flat surface, with the palm downwards, is turned so that the palm looks upwards; this is called *supination* of the hand and fore-arm. When the hand is again returned to its original position, the movement of *pronation* is performed. The joint between the upper ends of the radius and ulna is not, however, the only one concerned in the production of these movements. For a corresponding joint exists also at their lower extremities; only at this latter joint the radius has the concave surface, to which a convexity at the end of the ulna corresponds. The radius is the moveable bone, the ulna remaining in its position. So that, owing to the exactly opposite arrangement of the articular extremities of the two bones, during pronation and supination,

whilst the upper end of the radius rolls in the cavity of the ulna, its lower end may be regarded as revolving around the convexity of the ulna. The steadiness and delicacy of these movements are also increased, when the elbow is bent, by the cup-shaped cavity at the head of the radius receiving the small rounded surface of the part of the humerus corresponding to it. A sort of central point or axis is thus afforded, upon which the movements take place. Hence, when it is necessary to perform any movement with the fore arm, in which pronation and supination are to be called into action, and which requires either strength or precision for its execution, the elbow is always bent, for the radius now possesses a fixed point upon which it can move. This may be illustrated by the common operation of inserting a corkscrew into a cork. This is effected by the alternation of these two movements, and, as may readily be ascertained by trying it, is much more easily done when the arm is slightly bent, than when it is extended.

There is no movement, between the two bones of the leg, corresponding to that of pronation or supination performed by the two bones of the fore arm ; for the leg, being for the purpose of supporting the weight of the body, it is necessary that it should be strong and steady. Hence the joints between the upper and lower ends of the tibia and fibula are of such a nature as to allow scarcely any movement at all to take place between the two bones.

Owing to the ligaments connecting the different bones in a finger being lateral ligaments, the movements possessed by these bones are flexion and extension. These kinds of movements, together with the numerous joints, eminently adapt the hand for the performance of its various duties. Thus, the different joints in the fingers can be so bent that each finger may be made to assume the form of a hook ; the bending of the whole of the fingers, in this hook-like manner, enables us to suspend the whole weight of the body upon an object grasped by them. The movement that especially characterises the hand of man is that

of opposition; that is, by which the thumb can be made to oppose or touch any part of the palmar surface of the hand and fingers. This gives to the hand unusual power in grasping objects, and compressing them, if needful, with great force, whilst this force can be so nicely regulated, that movements requiring the most delicate manipulation can be undertaken with equal readiness.

Movements of Joints—The different movements capable of being performed by the joints, may be classed together under the names of gliding movement, opposition, and rotation.

The gliding movement is the most simple—it is merely the moving of two nearly flat surfaces upon each other. It is observed in the joints between the different vertebræ, and in the articulation between the occipital bone and first vertebra.

Nodding of the head, either forwards or backwards, is performed when the last two bones glide upon each other. In Fig. 7 (*a*), the smooth surface of the first vertebra, on which the occipital bone glides, is seen.

Opposition, or the angular movement, is the movement of a joint in opposite directions, as in bending a limb, flexion, and extension, making it straight again. Numbers of the joints are capable of performing these simple movements. Or the movement of a limb outwards, termed abduction, and inwards, adduction, the latter taking place when both thighs are brought together.

When a single joint can be both flexed and extended, abducted and adducted, it is then said to be capable of performing the movement of circumduction. The hip and shoulder joints furnish examples of this. This movement is very extensive in both these joints, for, by swinging either the arm or leg round, the tips of the fingers or toes can be made to describe a considerable circle.

Rotation, where a bone turns upon its own axis, is possessed, to a certain extent, by both the hip and shoulder joints, for if *the arm bone or thigh bone* be grasped, they may be made to

rotate partially upon their own axes. It is seen, however, in the greatest perfection in the joint between the first and second vertebræ of the neck. In Fig. 6 and 7, the parts between which the rotation is performed are represented.

Fig. 7 is a view of the first and second vertebræ, seen from above, the occipital bone having been removed.

- 1 First Vertebra (Atlas).
- 2 Second Vertebra (Axis).

Springing from the upper surface of the body of the axis is a strong process of bone (*b*).

This process fits into a sort of ring, formed by a hollow on the inner surface of the atlas (*c*), and a strong ligament stretching across between the sides of that bone, the transverse ligament (*d*). This process is still further kept in its place by strong bands which extend from the transverse ligament, upwards to the occipital bone, and downwards to the axis. In Fig. 6 the outer surface of these ligaments is seen from behind, the back of the occipital bone and the hinder part of the atlas having been removed in order to afford a view of the interior of the spinal canal, in which the process of bone and its confining ligaments are situated.

1. The Atlas.
2. The Axis.
3. Occipital Bone.
 - a. The Transverse Ligament.
 - b. The Ligament going from it to the Occipital Bone.
 - c. The Ligament passing down to Axis.

By means of these ligaments the strong process of the second vertebra is retained in its position. When the head is moved from side to side, *i.e.*, when it is rotated, the atlas, to which it is firmly connected by ligaments, revolves around this bony process, which thus acts as a pivot or axis, hence the name of axis applied to the second vertebra, from which it springs. The rolling movement is facilitated by the presence of two synovial membranes, (*e.e.*) Fig. 7, one of which is situated

between the front of the process and the atlas, the other lying between the back of the process and the transverse ligament. It will thus be observed that the nodding and rotatory movements of the head, take place at different joints, the first being between the occipital bone and the atlas; the second between the atlas and the axis.

In addition to the ordinary apparatus of ligaments and synovial membranes connecting the different vertebræ, there is placed between each of these bones a structure of a peculiar nature, which has been termed the intervertebral substance or cartilage.

This consists of a series of disc-like bodies, corresponding in shape to the vertebræ between which they are placed, and to which they are firmly united by their two surfaces.

Fig. 8 represents the upper surface of one of these discs. It is seen to be composed at its circumference of a number of layers, arranged in a concentric manner, and closely united together, the interior of the disc consisting of a soft spongy substance, which does not exhibit any regular arrangement.

Fig. 9 is a view of three of the vertebræ with the discs between them.

The discs vary in thickness in different parts of the spinal column. In the regions of the neck and loins they are thicker in front than behind, exactly the opposite being observed in the discs placed between the vertebræ of the chest. It is owing to this circumstance that the spinal column is not straight, but curved, being convex forwards in the two first-named regions, whilst it is concave forwards in the region of the chest. The anterior concavity of the spine in this region necessarily increases the size of the thoracic cavity, and affords a greater amount of space for the expansion of the lungs to take place in, during inspiration.

The intervertebral substance is highly elastic, a property which is of the most essential service; for the vertebral column contains in its interior the spinal canal, lodging the spinal cord, and

it has connected to its upper extremity the cranium, which contains the brain. Both the brain and spinal marrow are very delicate organs, and extremely susceptible of injury. To the spinal column is transmitted the whole weight of the body in its various movements of walking, running, leaping, etc. The elasticity communicated to it by the presence of these discs, preserves both the column itself, the spinal cord contained in its interior, and the brain placed at its upper extremity, from the injurious effects that would otherwise be produced by these movements.

In addition to the elasticity produced by the presence of the discs, the number of joints between the different bones of the column, the bony surfaces of each joint possessing their own plates of elastic cartilage, and the peculiar elastic ligaments between the different arches of the vertebræ, add considerably to this property.

A very curious circumstance has been observed with regard to the height of the body at different periods of the day. If a person has been standing during a great part of the day, or actively moving about, he is found to be about an inch shorter than he was when he arose in the morning. This is owing to the weight of the trunk pressing continuously for a length of time upon these elastic discs, so as to force the surfaces of the bodies of the vertebræ more closely together. Rest, however, in the horizontal posture, as in bed, by removing the cause of compression, enables the discs to recover their proper size.

CHAPTER IV.

THE MUSCLES.

THE muscles are the organs of motion—that is they are the agents by means of which the movements, either of the whole body, or *its individual parts*, are effected.

The muscles are divided into two great classes.

Those composing the first class are the true organs of locomotion, the agents by which the body is moved about from place to place. These are called Voluntary muscles, for they are under the power of the will.

Those making up the second class are placed within the cavities of the body. They possess no power of changing the position of the body, for they act merely upon the organs to which they are connected. They are called the Involuntary muscles, for the will has no power over them.

It must be understood, that in this chapter the voluntary muscles are alone referred to.

Fig. 1 represents the muscles placed on the front of the body. Only the most superficial muscles are represented. That is those placed immediately beneath the skin and muscular fascia. Their natural position is observed. It must be understood, however, that beneath these muscles many others are situated, which cannot be represented in the figure.

Muscles of the Face, Head, and Neck :—

1. Muscle of the Forehead. This, together with a muscle at the back of the head, has the power of moving the scalp.
2. Muscle that closes the Eyelids. The muscle that raises the upper eyelid so as to open the eye, is situated within the orbit, and consequently cannot be seen in this figure. It is represented in Plate 8, Fig. 2, 3, the Senses.
- 3, 4, 5. Muscles that raise the Upper Lip and angle of the Mouth.
- 6, 7. Muscles that depress the Lower Lip and angle of the Mouth. By the action of the muscles which raise the upper lip, and those that depress the lower lip, the mouth is opened.
8. Muscle that draws the Lips together, so as to close the Mouth.
9. Muscle of the Temple.
10. Masseter Muscle. 9 and 10 are the two chief muscles of mastication, for when they contract, the moveable lower jaw is elevated, so as to crush the food between the teeth in the upper and lower jaws.
11. Muscle that compresses the Nostril. Close to its outer side is a small muscle that dilates the nostril.
12. Muscle that wrinkles the skin of the Neck.

13. Muscle that assists in steadying the Head, and also in moving it from side to side.
14. Muscles that depress the Windpipe and Organ of Voice. The muscles that elevate the same parts are placed beneath the lower jaw, and cannot be seen in the figure.

Muscles that connect the upper extremity to the trunk. Portions of four of these muscles are represented in the figure, viz :

15. Muscle that elevates the Shoulder.—Trapezius Muscle.
17. Great Muscle of the Chest, which draws the Arm in front of the Chest (Great Pectoral Muscle).
18. Broad Muscle of the Back, which draws the Arm downwards across the back of the Body (Latissimus Dorsi).
19. Serrated or saw-like Muscle, extends between the Ribs and Shoulder-blade, and draws the Shoulder forwards.

At the lower part of the trunk, on each side, may be seen the large muscle which, from the direction of its fibres, is called,

20. Outer oblique Muscle of the Abdomen.

Several muscles lie beneath it. The outlines of one of these,

21. Straight Muscle of the Abdomen, may be seen beneath the expanded tendon of insertion of the oblique muscle. These abdominal muscles by their contraction possess the power of compressing the contents of the abdomen.

Muscles of the upper extremity :—

16. Muscle that elevates the Arm (Deltoid Muscle).
22. Biceps, or Two-headed Muscle. Represented in Fig. 4.
23. Anterior Muscle of the Arm. This and the Biceps are for the purpose of bending the Fore-arm.
24. Triceps, or Three-headed Muscle. Represented in Fig. 5. This counteracts the last two muscles, for it extends the Fore-arm.
25. Mass of Muscles that bend the Wrist and Fingers, and pronate the Fore-arm and Hand—that is, turn the Hand with the palm downwards. They are called the Flexor and Pronator Muscles.
26. Mass of Muscles that extend the Wrist and Fingers, and supinate the Fore-arm and Hand—that is, turn the Hand with its palm upwards. They are called the Extensor and Supinator Muscles.
27. Muscles that constitute the ball of the Thumb. They move it in different directions.
28. Muscles that move the Little Finger.

Muscles that connect the lower extremity to the trunk. Several are represented in the figure.

29. Muscle usually stated as having the power of crossing one Leg over the other, hence called the Tailor's Muscle, or Sartorius; its real action is to assist in bending the knee.
30. Muscles that draw the Thighs together (Adductor Muscles).
31. Muscles that extend or straighten the Leg (Extensor Muscles).
One of these, viz., the straight muscle of the thigh, is represented in Fig. 2. The muscles that bend the leg are placed on the back of the thigh, so that they cannot be seen in the figure.

Muscles of the leg and foot:

32. Mass of Muscles that bend the Foot upon the Leg, and extend the Toes.
33. Muscles that raise the Heel—these form the prominence of the calf of the Leg. They are more fully represented in Fig. 6.
34. Muscles that turn the Foot outwards.

The muscles which turn the foot inwards, so as to counteract the last named muscles, lie beneath the great muscles of the calf, which consequently conceal them. The foot possesses numerous muscles, which act upon the toes, so as to move them about in various directions. These are principally placed on the sole of the foot, so that they cannot be seen in the figure. Only one muscle, which assists in extending the toes, is placed on the back of the foot. This is represented in the figure.

The above, although consisting of but a small number of the muscles of the body, yet serve to illustrate their nature and uses.

The names given to the muscles generally express either their position or size, their shape or uses. For example, the great pectoral muscle, 17. This receives its name of pectoral from its position. It is also called great, in order to distinguish it from the small pectoral muscle which lies beneath it.

Several muscles have the names of biceps or triceps given to *them*, because they possess two or three distinct heads of origin,

as in the biceps, 22, and triceps, 23, in the upper extremity. The name of extensor, or flexor, or elevator, expresses that that office is performed by the muscle so called.

The exact number of muscles in the human body varies according to the methods employed in enumerating them; about 400 may be considered as the received opinion.

The muscles are placed beneath the skin and the fat that is found under it; they are also surrounded, especially in the neck and extremities, by a strong membrane, called a *fascia*, which may be compared to a thin flattened ligament, for it is composed of the same tissue—the fibrous. It not only surrounds the whole mass of muscles, but it also sends thin partitions between the different muscles, so that each is separated from its neighbour by a fine piece of this membrane. In Plate VII., the Nervous System, this fascia is represented on one of the legs.

The use of this fascia is to retain the muscles in their proper positions during their action. For when a muscle contracts, a certain amount of movement necessarily takes place in it, so that, during violent action, it would have a tendency to slip or move out of its position. This is counteracted by this fascia, which binds the muscles together. Hence it is particularly well marked in all those parts, such as the extremities, where the muscular action is frequently strong and long continued.

The muscles are of a bright red colour, and constitute what is called the flesh. They make up the great mass of the body, the weight and bulk of the individual for the most part depending upon the volume of the muscles, whilst the height is owing to the length of the bones. The muscles in those parts of the body that are most frequently used, are larger and stronger than those found in parts less frequently employed; thus, the muscles on the right side, especially those of the right arm, are bigger and more powerful than the muscles on the left.

Divisions of Muscles.—From the figure it will be seen that the muscles present considerable differences in shape. They may

be divided, however, into the two great classes of broad and long muscles.

The broad muscles are met with in the trunk; some of the muscles of the face also belong to this division.

The great muscle of the chest (17) and the oblique muscle of the abdomen (20) are good examples of broad muscles.

The shape of these muscles especially adapts them for the positions that they occupy, for as they have most commonly to assist in forming the wall or boundary of a cavity, their expanded shape enables them to do this readily.

The long muscles are seen to the best advantage in the extremities; examples are also furnished by some of the muscles of the face and neck.

Naked Eye Structure of Muscles.—A muscle may generally be divided into three portions—a central part or belly and two extremities. The centre is commonly the largest of the three divisions, from which it in many instances gradually diminishes in size towards either end.

Fig. 2 illustrates these divisions. The muscle represented is the straight muscle of the thigh, which forms a part of the great extensor muscle of the leg.

a. Central Belly.

b. Upper Extremity.

c. Lower Extremity.

The belly is composed almost entirely of muscular fibres—the structure of which will shortly be explained—but the extremities consist of an entirely different tissue, called tendinous, which closely resembles in its structure that of ligaments already described. The tendons formed by this tendinous tissue are popularly called the sinews. From the tendon at one extremity the muscular fibres spring, from it they extend to be connected to the tendon at the other extremity; they come to an abrupt termination as soon as they reach the tendon, for the two tissues, tendinous and muscular, do not combine, being perfectly distinct *in their structure*. The manner in which these two tissues be-

come united varies in different muscles. In Fig. 2 the muscular fibres terminate on both sides of the tendon, like the barbs upon the shaft of a feather; they are then called doubly penniform. In other instances, they terminate upon one side merely, and then they are termed singly penniform. The tendons are connected to the bones, and thus they are the bond of communication between the muscular fibres and the bones.

Mode of Connection of Muscles.—The two extremities of a muscle are connected to different bones; in no instance are they attached to the same bone. In Fig. 2 the upper extremity is connected to the haunch bone (*d*), the lower to the knee pan (*e*), and, by means of the broad ligament extending from it, to the inner bone of the leg (*f*). These points are called the *origin* and *insertion* of the muscle.

When a muscle moves, it is said to contract, that is, its extremities approach closer together, the belly at the same time swelling up; by this contraction the two ends are approximated. This causes the two bones to which the ends are attached likewise to be drawn nearer to each other. In order that this may be efficiently performed, one end must be comparatively fixed, so that a steady firm point may be afforded upon which the muscle may draw; the fixed point is the origin of the muscle; the moveable, or that which is drawn towards the fixed, the insertion. In the straight muscle of the thigh, the end connected to the haunch bone being the fixed point, is the origin of that muscle, the end connected by means of the knee pan with the inner bone of the leg, the insertion.

The muscles of the face have only one extremity (the origin) connected to bone, the other (the insertion) being attached to skin of the face: owing to this peculiarity, when the facial muscles contract, they move the skin, and thus produce all those various expressions, by means of which the passions and emotions are depicted upon the human countenance.

There are certain of the muscles of the face that have no connection to bone at all; these are the muscles that guard the

openings of the eyes and mouth. Their shape is peculiar, for they are composed of a number of fibres arranged in the form of an oval or ellipse, the fibres surrounding the opening, towards which their concave margin looks. When they contract, the space between the fibres on the opposite sides of the ellipse is gradually diminished, until the orifice is completely closed. They are represented in Fig. 1 (2, 8) as in the contracted state, the mouth and eyes being shut. They are called orbicular muscles.

Muscular Action.—The extent of movement of a muscle is proportioned to the length and direction of the muscular fibres composing it. In the limbs, where great extent of movement is required, the muscles, as a rule, possess considerable length of muscular fibre. Amongst the most remarkable of these is the sartorius, 29, which possesses longer muscular fibres than any other muscle in the body.

Certain of the muscles of the extremities also possess very long tendons—a circumstance which enables them to be attached at some distance from the part that they move; if this were not the case, the limbs, instead of gradually tapering towards a joint, would be thick, heavy, and cumbrous at that part, owing to the necessary crowding together of a large mass of muscular fibres. The great length of tendon thus removes the two extremities of these muscles away from each other, so that they frequently pass over two or more joints, upon all of which they possess some influence, for when, during contraction, their action has been expended upon one joint, a continuance of the contraction enables them to act upon another.

The two muscles that bend the fingers furnish examples of this kind. These muscles are strong and fleshy in the fore-arm; but as they pass over the wrist-joint they become tendinous, the muscular fibres no longer existing in them. From each muscle a tendon passes to each of the fingers, one to be connected to the middle phalanx, the other to the last phalanx. As the *tendons pass along the front of the fingers*, they are confined in

strong sheaths by bands which are attached to both sides of each finger (Fig. 1 *a*.) A synovial fluid lubricates the interior of the sheath and the surface of the tendon, so that it moves with great ease and smoothness in the sheath which contains it. These tendons pass over the wrist-joint as well as the joints of the fingers. When they first begin to contract they bend the fingers; if this contraction continues they bend the wrist, so that by their action the entire hand is flexed upon the fore-arm.

As the extent of movement of a muscle is regulated by the length of the fibres, so the power of contraction is proportioned to the number of fibres contained in it. Short muscles, containing a considerable number of fibres, may thus possess great strength of action. Amongst these may be mentioned the temporal and masseter muscles, which are such important agents in the process of mastication.

When a muscle contracts, it does so by the influence of the Will. When we desire to perform an action, such as raising the arm, we *will* that the muscles by which this is performed should contract, and the arm is elevated. This action in most instances is so rapid, that there is scarcely an appreciable interval of time between the willing and doing of the action.

The Will possesses the power of decreasing and of increasing the force of muscular contraction up to a certain extent; and it can estimate, in the great majority of instances, the amount of force that has to be exercised in the performance of a given movement.

The will is the natural stimulus for exciting muscular action, the stimulus being conducted by the nerves which proceed from the brain or spinal cord to be distributed in the muscle, in which, in a manner that cannot be explained, it induces contraction. All the voluntary muscles are thus brought under the influence of the will, some apparently to a greater extent than others. For there are certain muscles, whose structure exactly corresponds to that of the voluntary muscles, yet which are only partially *controlled by the will*. The most important of these are the

muscles subservient to respiration, the action of which the will can only control for a short period. The nervous force induced by the will is the only agent in the living body which naturally excites the action of the voluntary muscles. Certain other stimuli may be made to induce artificially their contraction. The most remarkable of these is electricity, a current of which, if sent either through a muscle, or through the nerve going to it, induces contraction.

Any one of the numerous movements of the body, however simple it may appear to be, is but rarely executed by a single muscle, for the muscles are generally grouped together, and associated for the production of regular movements.

The muscles are so arranged on the various parts of the body that they antagonise each other in their actions,—for example, the muscles of the extremities on one surface possess different actions to those on the other; thus in the arm the groups of muscles in front bend it, those on the back make it straight again. When one set contracts, it has not only to move the arm, and anything that may be connected to it, but it has also to overcome a certain amount of resistance offered by the muscles of the other set, which are called the opposing muscles. When the muscles on both surfaces contract at the same time, and with the same amount of force, then the part no longer moves.

The same arrangement of the muscles into groups, with opposing actions, is seen in the lower as well as the upper extremity. By the alternate action of these groups the limb is bent and made straight again, as in the act of walking. During exercise, especially if it is violent, the contractions and relaxations of the muscles alternate with each other with great rapidity. As these are taking place, certain changes occur in the substance of the muscle, by which its particles are, as it were, wasted or worn away. When this has gone on for some time, the muscle *tires*, and that feeling of fatigue is produced, which, as is well known, *always accompanies considerable exertion*. If the muscle is now

allowed to rest, it gradually recovers itself, and is again enabled to perform its usual functions.

Microscopic Structure of Muscles.—The structure of a muscle is peculiar.

Each muscle may be readily split up into a number of bundles, depending upon its size. Each bundle is separated from its neighbour by an exceedingly thin and delicate partition, proceeding from the inner surface of the fascia, already described as investing the circumference of the muscle. Each of these bundles can be again subdivided into a number of distinct fibres.

These are represented in Fig. 3.

If any one of these fibres (*a*) is examined under a powerful microscope, it will be seen to be composed of a number of most minute threads called fibrillæ. The cut ends of these are seen in the figure. These fibrillæ are closely packed together, and surrounded by a transparent membrane (*b*), which retains them in position. The membrane has been removed from the outer surface of a few of the fibres (*c*), and the fibrillæ separated from each other. The fibres exhibit, when highly magnified, transverse lines upon their exterior. This circumstance has given to the voluntary muscles the name of transversely striped. Between the fibres the small blood-vessels (*d*) that carry blood to the muscle are seen. The structure above described alone possesses the power of contraction, for the tendon has no contractile power; hence it must be considered merely as the inelastic strong band of connection between the contracting tissue and the part upon which it acts.

Leverage of Muscles.—The attachment of the muscles to the bones, and the manner in which they move them, furnish examples of the different classes of levers.

The third kind of lever, where the power is placed between the fulcrum and the weight, is the one most commonly met with. Numerous examples of it are furnished in the muscles that bend the extremities.

Fig. 4 is a view of the biceps muscle of the arm, illustrating

this form of lever. Here P represents the place of attachment of the muscle to the radius; it is the point at which the power or motive force is applied. F, the fulcrum, is at the elbow joint; and R, the weight, or resistance, at the hand. When the muscle contracts, the fore-arm is bent upon the upper arm, the hand describing a curve as in the dotted line. This kind of lever appears to act in a disadvantageous manner, for the power is attached to the bone close to the fulcrum or centre of motion, and thus a greater amount of force has to be expended in producing a given result, than would have been the case supposing the power had been attached nearer the weight; but what is lost in power is gained in velocity, for R has to move through a large space in the same time that P moves through a much smaller one, and thus greater velocity is necessarily communicated to it, the rapidity of movement being equivalent in its usefulness to the loss of power. This property of rapid motion is more adapted to the requirements of the animal body than mere force of movement; for a succession of less powerful, but quickly succeeding blows, produces the same, if not a greater effect, than fewer, though more forcible ones.

The power of the muscle is, however, increased as its action is continued, for at the first the tendon is inserted at an acute angle into the bone, but as the action goes on it is placed at a right angle to it, which is the most favourable for its action.

Examples of levers of the second class, where the power is at one end, the fulcrum at the other, and the weight intermediate, are rare in the human body. The best instance is furnished by the muscles that depress the lower jaw, which are inserted into the inner surface of the chin on each side of the middle line,—these constitute the power; the fulcrum is the joint of the lower jaw, the resistance to be overcome being the antagonistic power of the muscles of mastication, Fig. 1 (9, 10), which are intermediate to the power and fulcrum.

There are several instances of levers of the first kind, where *the power is at one end*, the weight at the other, and the fulcrum

intermediate. These are more especially seen in the extensor muscles of the upper extremity.

Fig. 5 is an illustration. The power *P* is furnished by the attachment of the great extensor muscle of the fore-arm into the olecranon process of the ulna; *F*, the fulcrum, is at the elbow joint, and *R*, the weight or resistance offered by the hand.

Fig. 6 has been generally looked upon as an illustration of a lever of the second class. It represents the large muscles of the calf, which, from their attachment to the bone of the heel, raise it, together with the body, from the ground in the act of walking, etc. It must be regarded, however, as a lever of the first kind, in which the power *P*, as in Fig. 5, is placed in a disadvantageous position, being connected to the bone close to the centre of motion *F*; the resistance *R*, is at the earth, where the toes touch it, but as the ground, unlike the hand in Fig. 5, cannot be moved by the muscular contraction, the body is reacted upon, and it, together with the fulcrum, is raised. This happens whenever we stand on tiptoe. If the foot is raised from the ground, and the same muscles put in action, the foot moves and not the body, for the ground no longer supporting it, the muscles act with sufficient power to overcome any resistance offered by the foot.

CHAPTER V.

GENERAL MECHANISM OF THE FRAME.

THE various structures that have been described in the preceding chapters, viz., the bones which constitute the supporting parts—the ligaments which bind them together—the joints, the surfaces at which the movements take place—and the muscles, the agents by which these movements are effected—may be classed together as the organs of locomotion. A short space may now

be usefully devoted to the consideration of some of the principles which regulate the position, attitudes, and general movements of the whole framework.

An inspection, either of the naked skeleton, or of the bones when clothed with their muscular covering, convinces us that the erect position is the proper attitude of man.

The leading facts that prove this view are as follows :—

The position of the head at the top of the spinal column. This is due to the articulation between the first vertebra and the base of the skull being placed almost in the centre of the latter, and not towards the hinder extremity, as in animals.

The position of the face at the front of the head, and below the brain, the lower part not projecting before the upper, so that all its parts are almost on the same plane. Hence it is a matter of great difficulty to pick up anything with the mouth from a flat surface, as the ground ; so that there arises a necessity for hands and arms, by means of which food may be carried up to the mouth.

The spinal column does not present in man that concavity along the whole length of its anterior surface, such as is seen in other animals ; although there is a curve with the concavity anterior in the thoracic part of the spine, which would have a tendency to throw the body forwards ; this is counterbalanced by a curve in the opposite direction in the vertebræ of the loins and the neck, so that a perpendicular line may be drawn from the first cervical to the last lumbar vertebræ.

The last of the lumbar vertebræ is connected to the broad upper extremity of the sacrum, which affords a wide basis of support ; this bone is attached, at its sides, to the widely expanded haunch bones, and, through the articulation of these, to the thigh bones, the whole weight of the trunk is thrown upon the legs, the bones of which, for this purpose, are of considerable length and strength.

From the width of the haunch the thigh bones are placed *considerably apart at the upper end*, but incline towards each other

at the knee, the upper ends of the tibia being broad and strong, in order properly to receive and support them.

The foot is large and broad, placed at right angles to the leg ; the surface, called the sole, resting upon the ground, which it touches behind at the heel, and in front at the toes. It is arched in the middle, the hollow of the arch being turned to the ground, upon this arch the weight of the body necessarily falls.

The movements of the legs, although sufficiently free for the performance of their proper office, viz., that of propulsion, are yet far less extensive than those of the arms, as they have not merely to move the body, but also to support its whole weight.

The arms, from their structure and extent of movement, are evidently not intended to afford support to the body. The free and varied actions of the shoulder joint; the less extended yet more delicate movements at the elbow joint, especially those performed between the two bones of the fore-arm, termed pronation and supination; the numerous minute yet decided movements of the hand and fingers, more particularly those by which the thumb can be opposed to the rest of the fingers, by which the power of firmly grasping an object, prehension, is attained, all point to some other purpose than that of mere support and propulsion.

The mass of muscles found on each side of the elbow joint are beautifully adapted to the movements of the articulation, and the general purposes of the upper extremity. If the arm bones are examined when the ligaments alone remain connected to them, it will be seen that when the elbow is bent, the fore-arm is drawn upwards and inwards, the palm of the hand touching the front surface of the body and the face; this is evidently designed to afford protection to those parts in case of attack, and also to convey food to the mouth; the contrary movement of extension draws the fore-arm backwards and outwards; the muscles by which these movements are effected being placed at those points where they can best perform them, the flexors which bend, and the pronators which draw the arm inwards, arising from the inner border

towards which they draw ; and the extensors which straighten the arm, and the supinators that draw it outwards, arising from and drawing towards the outer border.

The erect position being the natural attitude of man, it is necessary, in order to maintain it, that the centre of gravity be properly preserved.

When the body is perfectly straight, and the arms parallel with the sides, it has been found that the centre of gravity corresponds to the centre of the sacrum, about its second bone ; its position, however, necessarily varies with every movement either of the trunk or the extremities.

The basis of support of the body is the space included between the outer sides and extremities of the two feet ; so long as a line drawn from the centre of gravity falls within this space, the body will not fall. In the ordinary position of standing, the toes are turned outwards, which, by increasing the space between the feet, increases the basis of support. This is still further augmented when the legs are drawn from each other, so that the feet are placed still further apart. If, by leaning in any direction, the line falls without this basis, then the body falls. If the basis of support is diminished either by standing on one foot, or by the feet resting upon a narrow ledge or other confined space, the body is prevented from falling to the ground, only by being carefully balanced ; that is, by a line drawn from the centre of gravity falling within the surface, however limited, upon which the foot is situated.

A few words may be said upon the two most frequent acts of progression, viz., walking and running. The act of walking consists in the trunk being carried forwards, first upon one leg and then upon the other, by the alternate advancement of the limbs.

Suppose a person to be standing erect, one leg being a little in advance of the other. The body inclining slightly forwards is pushed in advance by the extension of the limb which is behind, *so that its weight falls more and more upon the advanced leg,*

which is shortened at the same time by the bending of the knee and ankle. As the limb behind continues to push the trunk still further forwards, its heel for this purpose being raised from the ground by the action of the large muscles of the calf, and by straightening the knee, the toes and fore part of the foot being forcibly pressed against the earth, the trunk comes at last to be so far in front of the advanced limb, as to be no longer safely supported by it, and then the limb behind is raised from the ground by bending its knee, and allowing it to swing forward by its own weight, guided by the muscles, until the toes touch the ground in front of the opposite limb. A step has now been made, and the limbs are in a corresponding but opposite position from that in which they were when the step commenced. A repetition of the same act constitutes another step, and so their alternate action continues. The limb, therefore, being suspended from the trunk at the hip-joint by atmospheric pressure, swings forward, like a pendulum, under the action of gravity, when the foot is raised from the ground behind, during the forward movement of the body; the point where it touches the ground again in front being determined by the agency of the muscles under the control of the will of the individual.

At one moment in each step both feet touch the ground at the same time, that is, when the hind foot presses against the earth.

The act of running consists merely in a repetition of the same movements as that of walking, being performed only with much greater rapidity. This increased velocity causes both the feet never to touch the ground at the same moment of time, whilst they are both raised from it at the same instant; running thus becomes a succession of small leaps, the body being forcibly propelled through the air, one foot always being in advance of the other.

CHAPTER VI.

THE HEART AND ARTERIES.

THE organs of locomotion, described in the preceding chapters, together with the organs contained in the interior of the cavities of the body, require that they should have regularly and constantly passing to them a supply of the fluid called blood, by which they are nourished, that is, kept in a state fit and proper for the performance of their necessary duties. The means of conveyance are furnished by the presence in the body of numerous tubes or pipes of various size, called Blood-Vessels. Some of these proceed to the organs, and convey pure blood for their nourishment—these are called Arteries; others pass away from the organs, carrying in their interior the blood which has become impure by going through the organ—these are called Veins.

The arteries are continuous with the veins, not directly, but through the intervention of a number of minute hair-like tubes, called Capillaries. The blood is forced along the blood-vessels by the contraction of a muscular organ, called the Heart.

In the present chapter the heart, the arteries, and the capillaries, will be described; in the succeeding one, the veins, with the course and peculiarities of the circulation.

THE HEART.

This is an organ of a somewhat conical shape, its base being the highest part, and its apex the most depending portion. It is placed in the cavity of the chest, Fig. 2, lying almost in its centre, between the breast bone and the spinal column; having on each side one of the lungs. It projects, however, a little to the left side; its apex may be felt pulsating on this side in the space *between the fifth and sixth ribs.*

It must be regarded as the centre of the blood-vessels, for from it all the arteries of the body proceed either directly or indirectly, and to it all the veins gradually converge.

The heart is a large hollow muscle, and in its interior are four large cavities, which, during the alternate distensions and contractions of the organ, are either filled with or emptied of blood.

The human heart must be considered as a double one, for it can be divided into two separate halves, one on each side; each of them is distinct in itself, and does not possess any direct communication with the adjoining one. This division of the heart is marked out both on the front and back surfaces, the former only being seen in Figure 2 by a groove (*a*) extending from the broader upper end of the organ, or base, to the narrower depending extremity, or apex. In each of these grooves a small artery, called the Coronary artery, is placed; the anterior coronary artery is seen in the figure. The coronary artery is intended to convey the blood which nourishes the walls of the heart itself.

The two halves of the heart are called its right and left sides.

b. Right side.

c. Left side.

Each half is again subdivided into two parts, an upper smaller one, called the auricle, and a lower larger one, called the ventricle.

b. Right Ventricle.

c. Left Ventricle.

d. Right Auricle.

e. Left Auricle.

The auricles derive their name from the circumstance, that projecting from each of them is a prolongation shaped like an ear. The ventricles are so named because they form the greater part or belly of the heart. The line of division between the auricles and ventricles is marked on the surface by a groove, in which the coronary arteries are placed.

f. Posterior Coronary Artery of the Heart.

To the auricles the large veins proceed. The veins entering the right auricle are—

g. Upper hollow Vein (Vena cava).

h. Lower hollow Vein (Vena cava).

By the upper vena cava, all the blood from the body above the midriff or diaphragm enters the heart, and by the lower vena cava all the blood from the body below the diaphragm.

The veins entering the left auricle cannot be seen in this figure, for they are placed behind the auricle. They are named the pulmonary veins, for they return the blood from the lungs.

From the ventricles pass the large arteries. From the right ventricle, the large artery for the lungs *i* (the pulmonary), which divides at *k* into two branches, one for the right, the other for the left lung. From the left ventricle proceeds

l. The Aorta,

the largest artery in the body, by which is conveyed the blood that flows throughout the system.

The heart, with the commencement of the large vessels above described, is contained in a kind of bag, called the Pericardium, by which it is retained in its proper position. The inner surface of this bag, together with the outer surface of the heart, are covered by a perfectly smooth and glistening membrane, similar in its appearance to the synovial membrane of the joints, and having the same office. For the heart, as it propels the blood along the arteries, has alternately to dilate and contract; it is thus continually changing its size, and also to a small extent its position. The smoothness of the membrane permits these changes to take place without any of the evil consequences attendant upon undue friction occurring.

In Fig. 3 the front surface of the heart, seen in Fig. 2, has been removed, in order to expose the four cavities in the *interior*.

- b. Right Ventricle.
- c. Left Ventricle.
- d. Right Auricle.
- e. Left Auricle.

The muscular partition, *p*, separating the two ventricles from each other, as well as the partition, *p*, separating the two auricles, is also seen.

The opening of these three vessels into the right auricle may be observed.

- g. Upper Vena Cava.
- h. Lower Vena Cava.
- i. Coronary Vein.

The coronary vein returns to the auricle the blood that has been carried to the wall of the heart by the coronary arteries. Its orifice is guarded by a small valve.

The orifice of the lower vena cava is also guarded by a valve (*s*), but the upper vena cava has no valve protecting it.

This cavity communicates with the right ventricle through *u*, indicated by the arrow. At this opening is the large valve (*v*). The right ventricle again opens at *i* into the pulmonary artery, the valve (*w*) being at the orifice.

Opening into the back of the left auricle are the four large pulmonary veins (*x*) proceeding from the lungs. There are two on each side. They do not possess valves. This cavity communicates with the left ventricle, a valve (*y*) being situated at the place of junction. This ventricle opens into the aorta (*l*), and here also a valve (*z*) is placed.

The cavities above described are bounded by the contractile muscular walls of the heart. The valves situated at the various orifices are all represented as being open.

In Fig. 4 the arteries and auricles have been removed; the ventricles, with the valves separating them on the one hand from the auricles, and on the other from the arteries, being shown. The valves are all represented as closed, their upper surfaces *being seen*.

- b. Right Ventricle.
- c. Left Ventricle.
- i. Pulmonary Artery.
- l. Aorta.

The valves that separate the ventricles from the auricles differ both in shape and structure from those that are placed between the ventricles and arteries.

The auriculo-ventricular valves are composed of two or more triangular pieces, called cusps, which are attached together at their bases, that is, at the circumference of the opening, but their apices project inwards towards the cavity of the ventricle. The valve between the right auricle and ventricle possesses three cusps—it is called Tricuspid (*v*); that between the left auricle and ventricle has only two cusps—it is called Bicuspid (*y*). To the apices and margins of these valves, as well as to their posterior surfaces, strong, yet slender fibrous cords are attached, seen at *m, m, m, m*, Figs. 3 and 4; the cords by their other extremities being connected to rounded muscular columns (*n, n*), Fig. 3, which project from the inner surface of the walls of the ventricles.

The valves between the ventricles and arteries (*w, z*), Figs. 3 and 4, are both composed of three separate pieces, each piece possessing a crescentic or half-moon shaped form. They are connected by their crescentic margin to the line of junction between the artery and the ventricle, their loose margin and hollow surface looking towards the cavity of the artery.

Circulation through the Heart.—The circulation of the blood through the heart, with reference to the action of these valves, may now be considered.

The blood flows into the right auricle through the mouths of the large veins opening into it, and when this cavity has become distended, its walls contract so as to expel the blood into the right ventricle, the valve between the two being thrown back against the wall of the ventricle, as is seen at *v*, Fig. 3, so that the aperture is fully open, at the same time the valves guarding *the orifices of the lower vena cava and coronary vein* assist in

closing up the mouths of those tubes, so as to prevent the blood flowing back along them. The superior vena cava, since it does not possess a valve, permits to a slight extent the regurgitation of blood.

The ventricle, by this means, becomes distended, and, in its turn, contracts, so as to force the blood into the pulmonary artery, the valves at the commencement of which are thrown backwards against the wall of the artery, *w*, Fig. 3. In order to prevent the blood at the same time returning into the auricle, the cusps of the right auriculo-ventricular valve are brought together so as to close the orifice, *v*, Fig. 4. The object of the attachment of the tendinous cords to the posterior surface and margins of the valve, is, that by drawing upon it, they may prevent its being forced too far upwards into the auricular cavity.

At the same time that the right auricle is filling, the left auricle also becomes distended by the blood entering it from the pulmonary veins. It then contracts and the blood flows onwards into the left ventricle, which becomes, in its turn, distended. Contraction of its walls then occurs, and the blood is forced into the aorta, and thus throughout the body. During the contraction, the aortic valves (*z*), Fig. 3, are opened, the left auriculo-ventricular valves, however, being closed (*y*), Fig. 4, so as to prevent the backward flow into the auricles.

The object of the valves at the mouths of the two large arteries is to prevent, in that recoil of the arteries which always takes place after their distension by the ventricular contraction, the backward flow of blood into the ventricles; for the valves are forced together by the recoil, and thus effectually stop the regurgitation of the blood. This closed condition is represented at *w* and *z*, Fig. 4.

The alternate distension and contraction of the auricles and ventricles, with the alternate opening and closing of the valves, is continually going on—taking place, on an average, about once in every second.

The contractions of the heart are quite involuntary, that



is, the will has no power over them. For the constant and regular movements of the heart are of the utmost importance in preserving the life of the individual. If these were liable to be interrupted or disturbed by the mere exercise of the will, then the life of every person would be placed entirely within his own control—a circumstance which it is wisely ordained should not be the case.

THE ARTERIES.

The arteries all proceed, either directly or indirectly, from the right and left ventricles of the heart. The large pulmonary artery, passing from the right ventricle to the lungs, will be considered in the chapter on the lungs. The aorta, from the left ventricle, is the great systemic artery, for through it and its numerous branches the blood is carried throughout the entire system, except that which passes by the pulmonary artery to the lungs.

The names given to the arteries for the most part express either their position in the body or the parts to which they are distributed.

In Fig. 1 a general view is given of the distribution of the arteries of the body. An outline view of the bones is also given, so that the position of the artery, with reference to the bone, may be seen. Where a pale tint is given to the artery, it is intended to represent that at that point it lies behind the bone. The arteries, for the most part, are covered by muscles and fascia; in very few instances are they placed directly beneath the skin.

The Aorta. 1. This vessel springs from the left ventricle of the heart at the upper part of the chest; it extends at first a short distance upwards, and then, changing its direction, passes across the front of the spinal column, so as to form an arch. It then courses down the side and front surface of the spinal column, as far as one of the last vertebræ of the loins, thus occupying the cavities of the chest and abdomen, when it divides into two large branches for the lower extremities. At the point of division, a small artery, 2, extends along the *front of the false vertebræ*. In animals possessing a tail, this

branch is considerably enlarged. From the aorta, as from a centre, numerous branches proceed. Thus three large vessels are given off at the upper part of the arch, of which two pass to the left side of the head and neck and left upper extremity; the third, very shortly dividing into two, passes to corresponding parts on the right side. As the aorta lies along the different vertebræ, it gives off numerous branches from its posterior surface, of which those found in the chest run outwards, one corresponding to the space between each rib, hence called intercostal arteries, 3, 3, etc. The corresponding vessels in the abdomen are the lumbar arteries, 4. From the front of the same large vessel, branches proceed in the chest to the gullet, windpipe, etc., 5; much larger ones being given off in the abdomen to the stomach, 6, spleen, 7, liver, 8, bowels, 9, and other contents of the cavity.

The artery passing to each arm extends as a large vessel, gradually diminishing in size, as far as the bend of the elbow, where it divides into two branches. It has received different names in different parts of its course; thus at 10, 10, it is called subclavian, from passing under the clavicle; at 11, 11, it lies in the arm-pit or axilla, and is called axillary; at 12, 12, when extending down the upper arm, brachial.

The two terminal branches of division correspond to the two bones of the fore-arm, and are called radial, 13, 13, and ulnar, 14, 14. The radial, which is placed just beneath the skin and fascia a little above the wrist joint, is the artery commonly selected for feeling the pulse. These two vessels pass to the hand, and form there, by joining together two arches, a superficial, 15, and a deep 16. From the superficial, branches pass to the fingers, one extending down the side of each finger; they are called digital arteries, 17, 17. At the end of each finger the branches that have passed down its sides join by forming an arch across the front, from which arch many small branches proceed to the skin of the tips of the fingers. The hand is thus most abundantly supplied with
by the numerous vessels in it; this is connected with its

great activity of movement, and also with its great sensibility. Along the whole length of the arteries above named, branches proceed at various intervals, which have received different names, and which pass to the muscles and other structures in the extremity.

✓ From the commencement of the large artery of the arm, a large vessel, the vertebral, 18, extends through a series of holes at the roots of the transverse processes of the vertebræ of the neck to the brain,

The large arteries, the carotid, 19, 19, extending up each side of the neck, reach nearly as far as the angle of the jaw, where they divide into two branches; of which one, the internal, 20, extends almost directly upwards to the interior of the skull, for the brain; the other, the external, 21, divides into several branches, which proceed to the tongue, teeth, and parts on the outside of the head. The arteries for the face, 22, and temple, 23, are seen. In many persons, especially in old people, the artery of the temple may be seen ramifying and pulsating beneath the skin.

The large artery for the lower extremity, called common iliac, gives off, 24, inner iliac, a considerable sized vessel, which divides into branches for the parts about the hip.

The main vessel continuing downwards along the brim of the pelvis, under the name of outer iliac, and along the front and inner surface of the thigh, as the femoral artery, 25, gives off at 26 a large artery, which, by its branches, supplies the numerous muscles of the thigh; most of these extend to the back of the limb to carry blood to the muscles situated there.* The femoral artery then runs to the back of the limb, being placed in the ham, 27, at the lower part of which it divides into two branches; of which one, called anterior tibial, 28, passes through between the bones to the front of the leg, and then downwards to the upper surface of the foot; the other, posterior tibial, 29, continues down the back of the leg to the sole of the foot; branches *proceeding from the arteries* of the sole to each side of the toes,

constituting the digital arteries. From the large arterial trunks in the leg many branches proceed, to carry blood to the different structures in the limb.

From the Figure, it will be seen that the arteries decrease in size as they pass from the centre towards the circumference of the body. They may be compared to a tree, the main trunk of which is the aorta, whilst the different vessels proceeding from it, either immediately or mediately, are the primary and secondary branches. One large vessel passes to each extremity, extending down the upper part of the limb, and giving off several branches without diminishing much in size, finally dividing into two branches, which extend along the lower part of the limb, in the upper extremity, to the hand, in the lower, to the foot.

These large vessels are placed on the surface of the limb that becomes concave in the act of flexion; thus the large artery of the ham, in order that it may follow this rule, passes in that space to the back of the limb, for the back of the knee is the concave surface when the joint is bent. This is for the purpose of affording greater protection to the vessels, which, if placed on the convex instead of the concave surface, would not only be more exposed to external injury, but would also be liable to be torn in the movements of the limb.

The arteries of the face ramify tortuously upon it; this is for the purpose of accommodating them to the varying size of the face during the elevations and depressions of the lower jaw, over which bone the large arteries of the face proceed.

The smaller branches of the arteries communicate with each other, the communication being technically called an *anastomosis*; this is seen in the arches of the palm. It is not confined to this region, but takes place throughout the body. This is of great importance, for if, through an obstruction in the channel of one of the arteries, the blood should be prevented going to a part, it would find its way there through the communications which this vessel has with the adjoining ones.

The term *artery*, from a Greek word signifying air, was given

to these vessels by the ancient Anatomists, because they supposed them to contain air. They convey, however, blood. Their cavity has no communication with the exterior of the body, for whilst they terminate by one extremity through their main trunk with the heart, by the other they are connected through the capillaries with the veins. They are cylindrical tubes or pipes, possessing walls of considerable strength and elasticity, the thickness of the wall and the diameter of the canal in the interior, being regulated by the size of the vessel.

Structure of the Arteries.—Several distinct tissues make up the wall of the arterial tube. The outer part is composed of fibrous tissue, and upon this the strength of the arterial coat chiefly depends. Beneath this a peculiar tissue, called the yellow or elastic tissue, is seen; represented in Fig. 5, as considerably magnified. It consists of flattened fibres or bands, which branch at their extremities, at the same time curling upon themselves. To the presence of this tissue the artery owes its elasticity. The arteries also possess the power of contraction, by which the diameter of the tube can be considerably diminished. They derive this property from the presence of *involuntary* muscular fibres in their walls. These fibres, although possessing the power of contraction, are completely independent of the action of the will. The inner surface of the artery is lined by a perfectly smooth membrane, which permits the blood to flow along it readily, and without obstruction. This membrane is prolonged into the heart, and lines the whole of the inner surface of the cavities of that organ.

The elasticity possessed by the arteries is of essential service to them, for when the blood is propelled into the aorta by the contraction of the left ventricle of the heart, the coats of the artery become dilated, in order to accommodate the interior of the tube to the increased quantity of blood forced into it; for the blood cannot flow off by the capillaries as rapidly as it is forced in by the heart.

When the contraction of the ventricle ceases, no more blood

being forced into the artery, its distended elastic walls recoil and press upon the blood in the interior of the tube, a portion of which is at first pressed back towards the heart. This blood passes into the slight hollow between the valve at the mouth of the artery and the wall of the vessel, and forces the valve backwards so as to close the opening, and thus prevent its further backward flow into the ventricle. The blood has now no course left but to press onwards, and this it does into the capillaries, through which it must pass in order to reach the veins. As the large artery that springs from the heart has to bear the full force of the contraction of the ventricle, it possesses a greater amount of elasticity than any of the other vessels, for which purpose its walls are furnished with a larger quantity of elastic fibres. If the walls of the arteries, instead of being elastic were rigid and brittle, the pressure thus exercised upon them at such oft-recurring intervals, might cause their rupture.

The expansion of the artery, by which it lengthens itself, taking place with each contraction of the ventricle and its subsequent recoil, when it returns to its former calibre, on the termination of the contraction, conditions which occur on an average about once in every second, produce the phenomena of Pulsation, or the Pulse. This takes place in all the arteries of the body.

The muscular fibres above described as being found in the wall of the artery, do not by their contraction increase the flow of blood along its canal; for although they certainly possess the power of diminishing the diameter of the arterial canal, this is merely for the purpose of regulating the amount of blood to proceed to an organ at different times, according to the quantity that it may require. The force of the heart alone is quite sufficient to propel the blood along the various arteries into the capillaries.

The Capillaries.—The capillaries are the minute tubes, of the average diameter of 3000th of an inch, extending between the minute extremities of the arteries and veins. They have derived their name from their extreme hair-like fineness and delicacy.

Their walls are composed of an exceedingly smooth and delicate membrane, in which all traces of the fibrous, elastic, and muscular tissues of the artery have disappeared. These vessels freely communicate with each other (anastomose), and form a very fine net-work.

In Fig. 6 a representation of the mode of arrangement of the capillaries in one of the prolongations called villi, connected to the mucous membrane of the bowels, is given.

- a. The Artery.
- v. The Vein.
- c. The Capillaries extending between them, and forming a net-work by their numerous communications; the small bodies seen in their interior being the small globules of the blood.

This diagram may be taken as a good representation of the plan which regulates the mode of connection between the arteries and veins through the agency of these vessels. The exact manner of arrangement, however, varies somewhat in the different parts. For the greater part of the structures of which the human body is composed contain capillaries in a greater or less quantity. The nature of the structure generally determines the mode of arrangement of these blood-vessels in it.

The contraction of the heart is of sufficient power to force the blood from the arteries through the capillaries into the veins, although the rate of passage of the blood in the capillaries is probably influenced to some extent by these small vessels.

Fig. 7 represents a highly magnified view of the corpuscles or globules of the human blood, but their description will be deferred to the chapter on the blood.

PART SECOND.



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HUMAN ANATOMY AND PHYSIOLOGY.

PART SECOND.

CHAPTER VII.

THE VEINS.

IN the last section, the vessels or tubes that conveyed the blood from the heart to the different parts of the body, viz., the arteries, together with the fine terminations of these vessels, viz., the capillaries, were described: in the present section, the vessels along which the blood, after having traversed these parts, is returned to the heart, will be considered. Following the same course that has been hitherto pursued, a general view of the structures to be described will be first given.

FIG. 1 is a general view of the distribution of the veins.

In examining this figure, it will be interesting to compare it at the same time with the view already given of the arrangement of the arteries, when the great resemblance between the course and position of the two sets of vessels cannot fail to be remarked. It will be seen, however, that the veins exceed in number the arteries; for in many places in the arterial figure, as 13, 14, and elsewhere, where only one artery is to be seen, at the corresponding places in the venous figure, two vessels will be found. This rule of two veins accompanying each artery holds good with respect to the smaller arteries only, for the larger arteries have but a single vein accompanying them. The veins, in fact, for the most part closely accompany the arteries; so that both

the vessel that carries blood to the part, as well as the vessel that conveys it from that part, lie side by side. There are certain parts of the body, however, where the veins are found without any arteries corresponding to them. This arrangement is especially to be observed in what are called the superficial parts of the body, where a large number of veins may be seen directly beneath the skin, lying upon the strong membrane or *fascia* which invests the muscles and retains them in their proper position. These are called the Superficial Veins. They are represented in the figure lying upon the fascia of the left arm and leg. In the other parts of the figure the deep set of veins, or those that accompany the arteries, are seen.

Commencing with the right foot, the veins may be traced from the toes, passing over the back of the foot 1, to the leg, where they form two venous trunks 2, corresponding to the anterior tibial artery; these receive a considerable number of branches in their upward course, which proceed from the great mass of muscles lying on the outer side of the leg. The veins that are represented in this leg in the lighter shade of blue, begin in the sole of the foot, and then pass upwards along the inner side of the ankle-joint, as at 3, to reach the back of the leg, along which they ascend 4, closely accompanying the posterior tibial artery, and receiving in their course numerous small veins that proceed from the muscles of the calf of the leg. At the upper part of the leg, the veins on the front pass to the back 5, and, after a short course, join those veins that, as above described, lie on the back of the limb. The large vein 6, formed by the junction of these, ascends behind the knee-joint, lying in the space called the ham, along with the large artery of the region. When it reaches the point 7, it leaves this space, and, passing to the inner side of the thigh, it ascends, at first on the inner side, and afterwards on the front of the thigh 8, along with the large artery called femoral, as far as 9, when it passes into the cavity of the abdomen. At the upper part of the thigh it receives the *large vein 10*, corresponding to the deep artery of the thigh,

which conveys back the blood that has been carried by that vessel to the numerous large and important muscles of the thigh. The femoral vein is also joined at this point by the large vein called long saphena, 11, formed by the union of the numerous small veins on the surface of the limb, as seen in the left leg of the figure. By the junction of these numerous veins, one large vessel, 9, is formed at the upper part of each thigh, which ascends into the cavity of the abdomen. The veins on the two sides receive in their course the smaller veins which ramify in the lower part of the walls of this cavity, as well as the large vein, 12, corresponding to the artery which conveys the blood to the organs contained in the cavity of the pelvis, and to the parts about the hip-joint. The large veins from each side of the body gradually converge, and, about the level of the last vertebra of the loins, join to form a single large vein, the inferior vena cava 13. The inferior vena cava ascends at the back of the abdominal cavity lying on the right side of the aorta. Several veins open into it, some, 14, proceeding from the walls of the abdomen, others from certain of the organs contained in it, 15. The greater number of the veins proceeding from the organs contained in the cavity of the abdomen do not open directly into the vena cava, but form a large vein called *portal*, which will be afterwards more particularly described. The vein then, at 16, passes through the diaphragm, enters the cavity of the chest, and terminates by opening into the right auricle of the heart. It is cut across in this figure just before its termination; its entrance into the heart may, however, be seen at *h*, figs. 2 and 3, in the representations of the heart.

Passing now to the deep veins of the right arm, it will be seen that they commence at the tips of the fingers, that they pass up the sides of the fingers to the palm of the hand, where they form an arch, 17, corresponding to the arterial arch of the palm; from this they extend upwards along the front of the fore arm, 18, as far as the bend of the elbow, closely accompanying the arteries of the fore arm, and receiving from the muscles numerous small

branches corresponding to the small arteries sent to those muscles. At the bend of the elbow, two veins result from the junction of these different veins of the fore arm, which pass up the inner side of the upper arm, 19, closely accompanying the brachial artery as far as the armpit, where they join to form a single large vein, the axillary, 20. They receive in their course many small branches from the muscles. The axillary vein receives, at 21 and 22, two large veins formed by the union of the numerous small superficial veins of the arm, seen in the opposite limb. Thus, in the upper as well as in the lower extremity, a single large trunk conveys away all the blood that has been circulating through the limb. This large vein passes beneath the collar-bone, reaches the lower part of the side of the neck, 23, where it is joined by the large veins that return the blood from the head and neck.

The veins that return the blood from the inner and outer parts of the head and neck are called the jugular veins, inner 24, and outer 25. Of these, the outer is the smaller. It may commonly be seen beneath the skin on the side of the neck. It returns the blood that has been circulating on the outer part of the head, 26; hence it must be regarded as a superficial vein, and must consequently be placed in the same category as the superficial veins of the limbs. The internal jugular returns the blood that has been circulating on the face 27, in the brain, and in the deeper parts of the neck. It accompanies the carotid artery, and must thus be regarded as a deep vein.

By the junction of these large veins at the root of the neck, a much larger vein on each side is formed. These gradually converge so as to form a single trunk, the superior vena cava, 29. The superior cava is placed at the upper part of the cavity of the chest, and to the right side of the first portion of the large artery called aorta. After a short course, it enters the upper part of the right auricle of the heart, as may be seen at *g*, figs. 3 and 4, in the representations of the heart.

The veins corresponding to the intercostal arteries, that run

between the ribs, do not open into either the superior or inferior vena cava, but pass to form a vein of considerable size which lies upon the vertebræ of the chest. This vein is called the azygos vein. It begins in the cavity of the abdomen, 30, 30, then enters the cavity of the chest, and, as it courses upwards, gradually increases in size by receiving the various intercostal veins, until it finally terminates, 31, by joining the superior vena cava.

Turning now to the extremities of the left side, the arrangement of the superficial veins may be examined. These are separated from the deep veins by the strong fascia binding down the muscles. They commence by very fine branches arising from the capillaries of the skin. If the back of the foot is examined, it will be seen that the veins proceeding from the skin of the toes form an arch, from the inner side of which a vein, 11, proceeds, called long saphena. This passes upwards along the inner side of the leg and thigh, increasing considerably in size in its course, owing to the number of branches joining it from the extensive surface of the skin of the limb. It terminates, as already mentioned, at the upper part of the thigh, by passing through a hole in the fascia, and joining the femoral.

The superficial veins of the hand commence at the tips and sides of the fingers, from which they proceed along the back of the hand, beneath the skin of which they may be distinctly seen. They then ascend along the fore arm, forming three large veins: the radial, 32, on the outer side; the ulnar, 33, on the inner; and the median, 34, in the middle. At the bend of the elbow, the median divides into two branches, of which one joins the radial to form the cephalic, 22; the other joins the ulnar to form the basilic, 21. Into one or other of the two branches of the median the surgeon generally makes an opening when he is desirous of drawing blood from the patient. The cephalic and basilic veins terminate by joining the deep or axillary vein, 20. The communications between the superficial and deep veins are not, however, confined to the point of termination of the former, but occur at various parts of their course, as at 35.

From the description that has now been given of the arteries and veins, it will be seen that the whole of the body is traversed by two distinct sets of tubes or vessels. The one, the arteries, commencing at the left ventricle of the heart as a centre, by a large vessel, the aorta, which gives off from its sides large branches—these in their turn giving off other branches,—the tubes, by this means, becoming smaller and smaller until they finally terminate in the minute hair-like vessels, the capillaries. The veins all commence in the capillaries as small vessels, which gradually unite together, so as to form larger and larger vessels, until finally, as they approach the heart, two large veins only are found, which terminate by opening into the right auricle of the heart.

Structure of the Veins.—The veins, so far as their general structure is concerned, correspond closely with the arteries. Their walls are, however, thinner. They possess, like the arteries, a smooth membrane lining their interior for the purpose of allowing the blood to flow easily along them. They differ from the arteries, however, in one important particular, viz., in the possession of valves.

Fig. 2 is an enlarged view of a vein cut open throughout the greater part of its extent, in order to exhibit the valves in the interior. These are generally arranged in pairs, as at *a, a*. The divisions of the valve are crescentic, or half-moon shaped; of their two margins, one, *b*, is attached to the wall of the vein; the other, *c*, lies loose in the cavity of the vein: of their two surfaces, one, *d*, looks towards the cavity of the vein; the other, *e*, looks to the wall of the vein,—between this latter surface and the wall of the vein is a small pouch into which the blood can pass. The valves may be situated either in the course of a vein, *a a*, or at the point of junction of a small with a large vein, *ff*.

Uses of the Valves.—The valves are so placed as to allow the blood to flow freely along the veins to the heart, but they effectually prevent the blood from flowing back again. Numerous communications, or *anastomoses*, take place between the different

veins lying in the same part of the body, not only of the deep veins with each other, and the superficial veins with each other, but also of the deep with the superficial veins. These anastomoses, owing to the valves that are so generally placed at the point of communication, exercise most important influences upon the passage of the blood through these vessels.

The valves are most abundant in the veins of those parts of the body where the circulation is likely to be interfered with by the action of the muscles, and by the pressure of the blood induced by its gravity. It is in the same parts also that the superficial veins are found. When the muscles contract during the movements of a part, they naturally press, to a certain extent, upon the veins running between them. This pressure, according to the laws regulating the motion of fluids, would have a tendency to force the blood partly forwards towards the heart, and partly backwards towards the capillaries. The backward movement would, of necessity, retard the circulation if allowed to go on, but as soon as the blood reaches the first pair of valves, it passes into the pouch, *e*, between the valve and the wall of the vein, forces the valves together, and thus completely prevents any further regurgitation. The blood has now to seek some other channel, by means of which it may pursue its course to the heart. This it finds in the communicating branches which connect the deep and superficial set of veins, along the latter of which it now passes; for these veins being separated from the muscles by a strong fascia, are necessarily not subjected to the same pressure as the deep veins. Hence this double arrangement of veins in a part is for the purpose of affording a collateral channel, along which the blood may pass to the heart during the contraction of the muscles of the part. Thus, during continuous exercise, the superficial veins always become distended with blood, so that their outline may be readily seen beneath the skin.

The extremities being the parts where the muscular movements are most violent, are most abundantly provided with superficial veins.

Movements of the Blood.—Along the vessels whose arrangement has now been described the blood is continually flowing. Numerous experiments show that the contraction of the left ventricle alone is productive of an amount of force sufficient to propel the blood through the arteries into the capillaries, through these into the veins, and so back to the right side of the heart.

It has already been shown that, owing to a larger amount of blood being forced into the arteries than can at once pass through the capillaries, a certain amount of the heart's action is expended in dilating the arteries. But as these vessels, by their recoil, assist in pressing on the arterial blood (its backward movement being restrained by the closure of the valves at the commencement of the aorta), it may be considered that the whole force of the ventricle is thus employed in urging on that fluid. The pressure exercised by the recoil of the arteries, taking place at a time when the ventricle has ceased to contract, and when, consequently, the blood has not the benefit of any direct force derived from this contraction, assists in a most material manner in its propulsion.

The pulse, which is produced by the alternate distension and recoil of the artery, thus affords an accurate guide to the number of the contractions of the heart; every beat of the pulse indicating a contraction of the ventricles.

It has been stated that the healthy average number of pulses, or ventricular contractions, are about 60 in the minute, or one in every second; but the number is often found somewhat to exceed this, and, in certain instances, to exceed it considerably, the health at the same time being quite good. Considerable differences in the number of pulsations in the minute are observed at different periods of life. In children they are much more frequent than in the adult. The position of the body also exercises a great influence upon the pulse; the *beats* being more numerous *in the same person when standing than when sitting, and when sitting than when lying down.*

The pulse cannot be felt in the very smallest arteries, in the capillaries and veins; for the blood flows through these with a continuous onward movement.

As the blood passes through the capillaries certain changes take place in it, consequent upon the attraction subsisting between some of its constituents and the structures lying on the exterior of these vessels. This attraction is supposed by many physiologists to assist, to some extent, in the circulation; but as a consideration of this question involves an inquiry into the physiology of nutrition, it had better be reserved for the present.

That the blood circulates or moves throughout the vessels, is a fact which has now for upwards of two centuries been recognised by anatomists. The fact of its doing so was first announced by Harvey in 1619. He was led to this conclusion by observing the continuous arrangement of tubes in which it is placed, and the valves placed at the origins of the arteries from the heart, between the cavities of the heart, and in the interior of the veins; the valves being so connected to the walls of the vessels, that while they afford every facility for allowing the blood to flow freely onwards, yet they put a most effectual bar to its backward movement. The close similarity, also, between the muscular structure of the heart and the other muscles of the body, indicated the source whence the motor power that impelled the blood was derived.

The improvements that have taken place of late years in the modes of conducting anatomical investigations have supplied anatomists with another proof of the circulation of the blood; for, by placing a transparent animal structure, such as the web of a frog's foot, or the wing of a bat, beneath the microscope when the animal is living, the particles of blood can be readily seen moving in the small vessels of the part.

CHAPTER VIII.

THE BLOOD.

THE blood is the important fluid which circulates through the entire body in the various tubes or vessels which have been described under the names of arteries, capillaries, and veins. It is the most important of the animal fluids; for it conveys to the various textures the materials by means of which they may make good the waste continually taking place in them from exercise or decay, and it also removes from these textures certain waste products formed in them during their employment and use.

When drawn from the body during life, it flows out as a red fluid, which, if it proceeds from an artery, has a much brighter colour than if it proceeds from a vein. In either case, if received into a cup or other vessel, certain changes soon commence to take place in it. In a few minutes, it begins to thicken, and very shortly separates into two distinct parts—a solid red portion called the *clot*, and a fluid portion, of a light yellow hue, the *serum*. This change is called the *coagulation* or *clotting* of the blood. The exact period elapsing between its being drawn from the body and its coagulation varies much in different instances. It seems to be facilitated by exposure to the air and agitation; circumstances which favour the evolution of a small quantity of ammonia from it, as has been lately determined by the experiments of Dr Richardson.

The chemical composition of the clot and serum present remarkable differences.

The clot consists of a material called fibrine, and of myriads of minute circular bodies called the corpuscles or globules of the blood.

The fibrine is the constituent of the blood upon which its coagulability depends. So long as the blood is circulating in the *vessels*, the *fibrine* remains in solution; but it possesses the

remarkable property of solidifying immediately after it is drawn from the body.

During its solidification it forms a number of very fine threads, which entangle in their meshes the corpuscles of the blood, upon the presence of which the red colour of the clot depends. The corpuscles are figured in Plate IV., Fig. 7.

These corpuscles are extremely minute bodies. In order to see them, a very high magnifying power must be employed, for they are not more than $\frac{1}{3500}$ th of an inch in diameter.

In their shape they have been compared to small pieces of coin; their surfaces, however, instead of being flat, are in some instances concave, in others convex.

Two kinds of corpuscles may be distinguished, the red and the white; the former are by far the most abundant.

The red corpuscles possess a remarkable composition—the metal, iron, most probably combined with oxygen, playing a most important part in their constitution.

The serum of the blood consists of water holding in solution the other constituents of the blood. These are both numerous and diverse in their composition. For as the blood is the only source through which the tissues can receive the materials from which they are formed, it follows that the blood must contain these different substances. Certain of the waste materials of the body are also found in it. These are all dissolved in the serum. The contents of the serum may thus be divided into building materials and waste products. The most important of the former is the substance called albumen; a compound which, in its properties, resembles the white of an egg. Numerous inorganic substances, chiefly in the form of salts, are also found dissolved in it; amongst the most remarkable of which is common salt, together with compounds of phosphoric acid, with potash, soda, lime, and magnesia. One of the most remarkable of the waste products in the blood is sugar; but as this, together with the class to which it belongs, is on its way to be separated from the body, it never accumulates, in healthy blood at least, to any great extent.

The blood also contains a small quantity of fatty matter dissolved in it. The peculiar odour of the blood is due to one of its fatty constituents. This odour is so characteristic, that it enables those accustomed to discriminate in such matters to distinguish the blood of one animal from that of another.

A certain variety, as regards quantity, amongst all the constituents of the blood, is quite compatible, however, with a healthy state of the system. This variety depends partly upon the nature of the food, partly upon the age, and partly upon the temperament of the individual. The blood of those who feed exclusively upon animal or vegetable food is found to possess certain differences. Under an animal diet, the solid constituents of the blood are more numerous than under a vegetable diet; the increase especially taking place in the quantity of the corpuscles. If the blood is examined shortly after taking a meal in which there has been a considerable quantity of fat, it presents a slightly turbid appearance, owing to the presence of fat in a minutely divided state. The amount of sugar in the blood is also found to be increased after a quantity of it has been eaten.

The red corpuscles are more numerous in the blood during the prime of life than in childhood or old age, and they are also more abundant in the blood of men than of women. These facts, bearing upon the amount of the corpuscles at the different periods of life, and in the two sexes, would appear to afford a clue to their peculiar use. It is probable that they are the especial source of the materials from which the muscles and nerves are formed, parts of the body which are so much more vigorous in the adult than in any other period of life, and in man than in woman. That diseased state of the blood, which is called poor blood, and which is consequent upon great diminution in the number of the red corpuscles, is always accompanied by considerable bodily and mental debility.

The albumen appears to be the material from which the blood-corpuscles are most probably formed; and thus, through the medium of these bodies, it assists in building up some of the *most important tissues*.

The fat of the body is derived from the fatty particles found in the blood. The sugar, and other waste products, are on their way to be separated from the blood either by the lungs, kidneys, or skin.

The inorganic constituents of the blood—and by this term, not merely the salts of the blood, but also the iron of the corpuscles, is included—although bearing a small proportion to the albumen, fibrine, and organic part of the corpuscles, yet exercise a most important part in the economy of the body. For the whole of the solid parts of the body contain certain of these substances, in greater or less proportion. In the nerves, muscles, tendons, and ligaments, they are in much less abundance than in the bones and teeth. The blood is the channel by which they are conveyed to these tissues. Certain of the tissues appear to have a preference for certain of these substances. Thus the bones and teeth contain much larger quantities of lime, combined with phosphoric acid, than of any other inorganic constituent. The different parts of the nervous system contain salts of phosphoric acid. The muscles and hair possess peculiar attractions for the iron of the blood. The muscles also contain a considerable proportion of the salts of potash. Upon the phosphate and carbonate of soda the chemical reaction or alkalinity of the blood is most probably due—a most important property of the blood—for it is upon this that its fluidity to some extent depends. It is somewhat difficult to form an opinion of the use of the common salt, although it is the most abundant of all the salts of the blood. It is the most generally diffused of the inorganic constituents, for it is found, in greater or less abundance, in all the tissues of the body. The various structures of the body, thus having affinities or attractions for certain constituents of the blood, possess the power of selecting from the blood, as it passes through the fine capillary vessels lying amongst them, those particular constituents for which they have a special attraction. So long as these different substances are in a proper quantity and quality in the blood, and so long as the tissues are in a healthy state to select them from the blood, the system will be preserved

in a state of health. It is in these localities also that the waste products already mentioned find their way into the blood.

The blood, in addition to the various solid constituents already described, has certain gases dissolved in it. These are oxygen, carbonic acid, and nitrogen: of these, the two former are the most important. Certain differences are observed between the amount of oxygen and carbonic acid in blood drawn from an artery and a vein. In arterial blood there is more oxygen and less carbonic acid than in venous blood. The difference depends upon this circumstance—that as the blood passes through the lungs, it absorbs from the air lying in the lungs a quantity of oxygen. This is carried by the blood flowing along the arteries to the capillaries. Here, in consequence of the changes taking place, the blood parts with a quantity of its oxygen to the tissues, and receives from them a quantity of carbonic acid, which is formed by the action of the oxygen of the blood upon the carbon of the tissues. The venous blood which now flows from the capillaries is thus charged with carbonic acid, which it conveys to the lungs. In the lungs, the blood parts with its carbonic acid to the air, and receives oxygen from it. The venous blood, by this means, becomes reconverted into arterial.

The cause of the difference between the colour of venous and arterial blood has been variously stated by physiologists. Some supposing that it depends upon the corpuscles in the two kinds of blood possessing different shapes, so that they reflect light differently. Others, and this appears to be the most probable opinion, regard it as due to a chemical difference between the action of the oxygen on the corpuscles in arterial, and the carbonic acid on the corpuscles in venous blood.

The quantity of blood in the human body varies very much in different individuals. It appears, however, to bear a relative proportion to the weight of the body. It has been estimated that the weight of the blood is to the weight of the body as 1 to 8;—so that, in a person weighing 160 lbs., the blood would weigh 20 lbs.

CHAPTER IX.

THE LUNGS AND RESPIRATION.

IN the previous section, it has been seen that the blood receives from the tissues, as it passes through the capillaries, certain waste products, which require to be excreted or separated from it. Amongst the most important of these is carbonic acid gas. This gas is separated from the blood in the lungs. The process by means of which this separation is effected is called the function of respiration. The lungs are the organs in which this function of respiration takes place.

In Fig. 3 the front of the chest has been removed, so as to give a view of the position of the lungs. The lungs, *a a*, are two in number, one being placed on each side of the chest. They are separated from each other by the heart, and great vessels connected to it, which lie between them. They are conical in their shape, resting by their bases on the upper surface of the large muscle called diaphragm, *b b*, which separates the chest from the abdomen. Their apices project upwards to the root of the neck. Their outer surface is in close contact with the inner surface of the wall of the chest. The exterior of the lung is covered by a perfectly smooth and glistening membrane, called *pleura*, which is also prolonged over the inner surface of the wall of the cavity in which the lungs lie. The perfect smoothness of the opposing surfaces of this membrane enables the lungs to move freely within the cavity of the chest, without sustaining, during respiration, any injurious effects.

In order to understand the mechanism by means of which the venous blood is purified from the carbonic acid it contains, the arrangement of the air-tubes and blood-vessels in the lungs must next be examined.

Fig. 4 gives a view of the air-tube, wind-pipe, or trachea, *c*. This is continuous by its upper end with the larynx, *d*, through which it opens into the back of the mouth. From this part it passes downwards into the cavity of the chest, and divides at *e* into two large branches, called *bronchial tubes*, *f, f*, one for each lung. These enter their respective lungs, and then divide and sub-divide into smaller and smaller branches, as may be seen in the figure. The different divisions of the air-tube are kept permanently open, owing to their walls containing, at intervals, rings or plates, *g g*, of a gristly elastic material, called *cartilage*, which effectually prevents the sides falling together. Thus an open passage is always provided for the upward and downward movement of the air. If any one of the small branches of the air-tube, as *h*, be followed out to its termination and highly magnified, as in *h*, Fig. 5, it will be seen to terminate by a closed end. But, before its termination, the walls of the tube become extremely thin and transparent, and dilate into a number of small pouches, called *air-cells*, *j*, each of which communicates with the interior of the tube.

Looking again at Fig. 3, it will be seen that a slice has been removed from the front of the left lung, so as to exhibit the course of the bronchial tubes, *f*, in it. Closely accompanying these tubes are the branches of the large artery called pulmonary, *i*, which springs from the right ventricle of the heart.

In Fig. 5, one of the branches of this vessel is shown running by the side of the bronchial tube, and, as that dilates into its pouch-like termination, the pulmonary artery divides into a great number of very small capillaries, *k*, which form a close and minute network on the outside of the pouches. From this network the rootlets of the pulmonary vein, *x*, arise, which join together so as to form the large pulmonary veins which enter the left auricle of the heart. Throughout the whole of the substance of the lungs, the pulmonary vessels and air-tubes are distributed in the manner now described; the substance of the lungs *being, in fact, made up of the divisions of these vessels.*

Movements of Respiration.—Such being the structures employed in the purification of the blood, it will be advisable, in the next place, to consider the movements, by means of which the air and blood are brought into contact with each other. For this purpose, a somewhat complex apparatus is provided.

The movements of respiration are divided into two kinds—one, that of Inspiration, when air is drawn into the lungs, the walls of the chest being elevated, and its capacity increased; the other, that of Expiration, where the air is expelled from the lungs, the walls of the chest depressed, and its cavity diminished.

By referring to Plate I., Fig. 1, it will be seen that the walls of the chest are formed by the ribs, which are attached in front, through their cartilages, *x*, to the breast-bone, whilst behind they are connected to the vertebræ of the chest, a moveable joint existing at each extremity. Occupying the spaces between each of the ribs are two muscles, called *intercostal muscles*, one placed outside the other, which are not seen in the muscular figure, because they lie beneath the great muscle of the chest. Portions of these muscles are represented in Plate V., Fig. 3, *m*. Connected with the first and second ribs, on each side, are two muscles called *scalene*, *n n*, which extend upwards to be attached to the transverse processes of the vertebræ of the neck.

In order to produce an ordinary inspiration, the outer intercostal muscle in each space contracts, and by this means the two ribs to which it is connected are elevated, the space between the ribs being at the same time increased. These muscles are not, however, the only agents by means of which the elevation of the ribs is performed; for there are certain small muscles connected to the ribs behind, called *elevators of the ribs*, which greatly assist. The scalene muscles also, *n n*, which represent in the neck the elevators of the ribs, raise especially the first and second ribs, increasing thereby the diameter of that part of the chest in which the apex of the lung lies. By this means, the diameter of the chest is increased from side to side. The elevation of the ribs at the same time *thrusts forwards* the breast-bone, which is very move-

able, and, to a slight extent, also thrusts backwards the vertebrae of the chest, so that the thoracic cavity sustains an increase in its diameter from before backwards. This is not all; for through the agency of the large muscle, the diaphragm, *b b*, the diameter is also increased in the direction from above downwards. This muscle, when in the relaxed condition, as represented in the figure, arches high up into the chest, so that its upper surface is very convex; but when it contracts, its fibres straighten, so that the muscle becomes much more flat, and thus affords increased space for the lungs in the lower part of the chest. Through these different agents, the chest expands in all its diameters. As this takes place, the lungs at the same time expand, by the air rushing into them, so that they remain closely in contact with the inner surface of the wall of the chest. In this manner is produced the movement of ordinary inspiration.

When a more violent inspiratory effort is required to be made, other muscles are called into play to assist in the elevation of the ribs. The head, the spine, and the shoulder-bones become fixed, in order to allow certain muscles passing from them to the ribs to draw upon the ribs, and thus increase the diameter of the cavity.

When the inspiratory movement has ceased, that of expiration begins. The walls of the chest, which are highly elastic, recoil, and at the same time press upon the lungs, so as to expel from them the air which had rushed in during the inspiratory effort. The recoil of the thoracic walls is also assisted by the action of certain muscles, such as the inner layer of the intercostal muscles, which, by drawing down the ribs, assist in the expulsion of the air. Expiration must, however, be regarded as essentially performed by the recoil of an elastic structure previously distended; receiving comparatively little aid from any muscular arrangements. These two movements alternate with each other during life, from 16 to 20 occurring every minute during the state of health. The interior of the air-passages, along which the air passes in *these movements of respiration*, is lined by a membrane, which

from its forming a moist and somewhat slimy secretion, has been called a *mucous membrane*. The surface of this membrane is covered by an immense number of the minute bodies, represented in fig. 6, magnified about 500 times. Projecting from their broader ends are the fine hair-like bodies, cilia, *a*, as they are called, which are continually moving in a direction away from the lungs towards the mouth. Their supposed use is to facilitate the passage upwards of the slimy material which is constantly in process of formation by the bronchial mucous membrane.

Dr Hutchinson has shown, by his experiments, that, in order to make a deep inspiration, the amount of muscular force to be exerted, in order to overcome the elasticity of the walls of the chest, and the atmospheric pressure upon the surface of the chest, is equal to raising a weight of 1000 lbs.

The movements of respiration belong to that class of movements which is termed *automatic*;—that is, they go on as it were mechanically, without there being any necessity for the will to determine that they shall take place. Yet, though essentially automatic, the will has to a certain extent power over them. Thus, it is quite possible to suspend the respiration for a few seconds; but very shortly the necessity of breathing manifests itself, and the respiratory efforts must again be commenced. If, through any cause, the breathing be suspended for a few minutes, death most certainly takes place.

Various familiar actions are only modifications of the two movements of respiration. Thus *sighing* consists of a long and forcibly drawn inspiration; whilst *coughing* is a forcible expiration, for the purpose of expelling some obnoxious material from the lungs or bronchial tubes.

Certain differences may be observed in the movements of the chest in the two sexes. In adult males, the lower part of the chest is more moveable than the upper; the contrary being the case in adult females.

As the function of respiration can only be properly carried on

by allowing perfect freedom of movement to the walls of the chest, it must be obvious that, in the arrangement of the dress, no means should be adopted to cramp or restrain the movements of the walls of this important cavity; for the amount of air that can be inspired and expired does not entirely depend upon the capacity or size of the chest, but is apparently greatly influenced by the mobility of its walls.

The name of *vital capacity* has been employed to express the amount of air that can be expelled from the lungs by a forcible expiration, after making the fullest inspiration. The height of the individual has been found to bear a very striking relation to this vital capacity. The average quantity of air that can be expelled by an adult male of five feet in height being 174 cubic inches, which may be regarded as his vital capacity. For every inch of stature above this, eight cubic inches in addition can be expired. So that an individual six feet in height would expire 262 cubic inches. However forcible an expiration is made, the whole of the air is not expelled from the lungs, a certain quantity always remaining in them. This has been called *residual air*, and it is in this that the interchanges between the blood and the air take place, which we will now consider.

Changes in the Air and Blood during Respiration.—The air or atmosphere is composed of a mixture of the two gases, oxygen and nitrogen, with a very minute proportion of carbonic acid, and a variable quantity of watery vapour, dependent upon the moisture or dryness of the atmosphere.

The venous blood, as it flows along the small capillaries of the pulmonary artery, contains a large quantity of carbonic acid gas dissolved in it. This blood becomes exposed to the action of the air lying in the air-cells; the air and blood being simply separated from each other by the thin transparent membrane forming the walls of the capillaries and the air-cells. An interchange now takes place between the gases of the blood and the *air in the cells*. The carbonic acid passes out of the *venous blood, through the moist permeable membranes forming the*

walls of the tubes, into the air-cells; whilst the oxygen of the air, passing in the opposite direction through the same porous membranes, enters the blood; the membranous walls of these tubes, owing to their extreme thinness and permeability, offering no obstruction to this interchange of the gases. The blood now flows into the pulmonary veins, having parted, whilst passing through the pulmonary capillaries, with its carbonic acid, and having received a considerable amount of oxygen; the change in its colour from dark purple to bright scarlet—that is, from venous to arterial blood, at the same time occurring.

The vessels of the lungs thus furnish an exception to the general statement, formerly made, that arteries conveyed arterial or pure blood, and that veins conveyed venous or impure blood; for, as has now been shown, the pulmonary artery contains venous blood, whilst the pulmonary vein contains arterial.

The blood also parts with a varying quantity of water in the form of vapour, the proportion depending upon the amount previously contained in the inspired air. The air, having lost a large proportion of oxygen, has acquired a considerable accession of carbonic acid and watery vapour, and in this form it is expired.

That such substances are contained in very evident quantities in expired air, may be readily shown by a simple experiment. If a glass, containing perfectly cold lime-water, be taken into a room in which a number of persons have been for some time assembled, in a few minutes a quantity of moisture will condense in drops upon the outside of the cold glass, and the lime-water it contains will become quite milky from the formation of carbonate of lime. In this manner, during every expiratory effort there is evolved from the lungs a quantity of carbonic acid—a gas which possesses noxious and even poisonous properties. From the lungs of a large mass of persons assembled in a room, the amount of carbonic acid exhaled into the atmosphere is very great; and, in a short time, unless means be taken to ensure, through *proper ventilation*, the entrance of a fresh supply of

pure air, and the exit of the impure, the atmosphere of the room acquires very deleterious properties. This manifests itself by producing in most persons fainting, and a general feeling of discomfort. If this is allowed to go on, death would ultimately ensue—an instance of which is afforded in the well-known account of the Black Hole of Calcutta, in which a number of persons were confined in a small room, during the night, without any fresh air being allowed to enter, when, out of 146 who were put in alive, 123 died. The crowding together of a number of persons in a confined space is thus to be most carefully avoided, unless means are taken at the same time to ensure a continuous influx of fresh air. The carbonic acid produces its poisonous effects, partly through its directly injurious action upon the system, and partly through the inspired air containing it possessing a smaller proportion of oxygen than is necessary for the continuance of human life. The blood, in these instances, becomes highly charged with carbonic acid, so that it exercises a most depressing influence upon the brain and other parts of the nervous system.

The nitrogen gas contained in the atmosphere plays but a very secondary part in the function of respiration. It appears simply to fulfil the purpose of diluting the oxygen, which, as has been frequently shown experimentally, if inspired pure, produces great and injurious excitement. The quantity of air passing through the lungs of a healthy adult during the day has been estimated at between 300 and 400 cubic feet; and it has been calculated that, in providing accommodation in rooms that are to be inhabited, at least 800 cubic feet should be set apart for each person.

Diagram of the Circulation.—By the aid of Fig. 7, a complete view of the circulation of the blood in the human body may now be obtained. This figure is merely to be considered as a diagram constructed for the purpose of giving as simple an idea as possible of the course of the circulation.

The venous blood is collected from the head and neck, trunk

and extremities, by the rootlets of the great venæ cavæ, *g* and *h*, and through these veins it is poured into the right auricle of the heart, *d*; from this it flows into the right ventricle, *b*, which propels it through the pulmonary artery, *i*, into the lungs. Here it parts with its carbonic acid and receives oxygen, having become converted into arterial blood. It then enters the pulmonary veins, *k* and *x*, and flows from the lungs into the left auricle, *e*, and from this into the left ventricle, *c*. By this it is propelled into the aorta, *l*, and through this vessel and its numerous branches throughout the whole body, to be returned to the heart again through the general venous system. That part of the blood which flows to the stomach and intestines, *n*, through their arteries represented by *m*, does not pass at once into the general venous system, but enters, by a distinct vein, called *portal vein*, *o*, the liver, *p*, through which it passes before entering the vena cava through the hepatic vein, *q*.

CHAPTER X.

ANIMAL HEAT.

IN connection with the subject of respiration, it may not be uninteresting to inquire how the heat of the body is produced and maintained. It is a fact that is now well ascertained, that in whatever localities the healthy human body is placed, whether exposed to all the cold of an arctic winter, or the intense heat of a tropical sun, it preserves, so far at least as regards the heat of the interior, an almost uniform rate of temperature. The heat of the surface of the body, especially that of the extremities, varies, however, greatly, according to the temperature of the external atmosphere.

This uniform temperature of the interior of the human body

is essential to the proper carrying on of the functions necessary to life.

In order that no extraneous cause may interfere with these functions, the body performs within itself the processes essential to the generation and preservation of the proper amount of heat. This power is not merely possessed by man, but is shared by all other mammalia and birds. Hence, they are all classed together under the name of *warm-blooded*. Fishes and reptiles, on the other hand, have their temperatures greatly influenced by the medium in which they live. This is, as a rule, lower than the temperature of man, so that they feel cold when touched. Hence they are called *cold-blooded*.

The average temperature of the interior of the body of man—say, for instance, the inside of the mouth—deduced from a great number of observations, is 100° . This temperature is derived from a low combustion, which is continually taking place throughout the whole system during life. The oxygen entering into the blood at every inspiration, as it passes through the capillaries, combining with certain of the constituents of the tissues, in order to form new and more simple compounds,—the most important of these combinations being with carbon to form carbonic acid, and with hydrogen to form water,—compounds which, we have already seen, are separated from the blood at every expiration by the lungs. It was formerly supposed that the union of the oxygen with the carbon and hydrogen took place in the lungs alone. If this had been the case, the temperature of the lungs would have been much higher than that of the other internal parts of the body, which is not so. Chemists have long recognised the fact, that chemical combination, whether taking place externally or in the interior of the body, always produces heat. By accurately calculating the amount of oxygen inspired during a given period, and the amount of carbonic acid expired during the same period, it has been estimated that the extent of chemical combination taking place during that time is nearly sufficient to produce the neces-

sary amount of heat,—the balance being made up by the heat generated in the combination of oxygen with hydrogen to form water.

The nervous system is found to exercise considerable influence upon the generation of heat ; for if the nerves going to a part be divided, the temperature of that part falls, from which some physiologists have supposed that the nervous system possesses the power of producing heat. This diminution of temperature may be explained, however, by the circumstance that the nutritive changes, which result in the combination of oxygen with the other elements, are much less efficiently performed when the nerves are divided or injured than when they are entire. Hence the amount of chemical combination taking place, and consequently the amount of heat produced, is not so great.

The function of respiration must thus be regarded as subordinate to the employment of oxygen, and to the production of carbonic acid in the interior of the body—that is, to the combustion which constitutes an essential part of the process of nutrition.

In a previous section, we have spoken of the blood containing fatty matters and sugar in solution. These materials play, to some extent at least, the part of the fuel, by the combustion of which the animal heat is generated ; for the oxygen contained in the arterial blood combines with the carbon and hydrogen of which these are composed more readily than with the elements of any of the other constituents of the blood. Hence, these have been described under the name of the *respiratory* elements of the blood. The deposits of fat which are found in so many parts of the body must also be regarded as storehouses, in which is laid up a large supply of fuel, or hydro-carbonaceous materials, which, in process of time, by gradually combining with oxygen, generates the proper amount of animal heat. In order to make up for the waste and destruction of these parts, which are continually going on, it is *necessary* that they should be constantly renewed.

This is effected by taking as food a proper amount of fatty and saccharine matters, or of substances which, by the act of digestion, can be converted into them.

In the very cold climates of the Arctic regions, where the external atmosphere rapidly tends to lower the temperature of the body, a large amount of fatty and oily materials forms a considerable proportion of the food. Travellers in those regions tell us of the enormous quantity of blubber that the Esquimaux devour at one meal. However disagreeable this may appear to those unaccustomed to such an oily diet, yet it is almost essential to the production and preservation of the proper amount of animal heat in those regions of excessive cold. In hot climates, on the other hand, where the demand for this excessive combustion is not so great, the food of the natives does not contain so large a proportion of fat.

As a forcible example of the use of fat in the animal economy, the phenomena of hybernation may be adduced. There are certain animals, such as the marmot and dormouse, which grow very fat during the summer and autumn. As winter approaches, they pass into a torpid condition. They live through the winter in this state, neither moving about, nor taking food,—the heat of their bodies, during this period, being maintained by the slow oxidation or combustion of the fat which had been stored up in the system previous to the commencement of winter. The fat being consumed by this process, they are necessarily at the end of winter spare and thin.

Man, above all animals, appears to have the power of living in the greatest range of temperature. This he is enabled to do, partly by the power he possesses of accommodating his food to the nature of the climate in which he is for the time residing; and partly also by the external aids, such as fire and clothing, which he is enabled to call to his assistance. Arctic navigators have experienced cold as low as 70° or 102° below the freezing point, whilst within the tropics the temperature is generally *above* 100° . A very high degree of artificial heat can be

experienced also without inconvenience. Men engaged in certain occupations, as in iron foundries and glass works, being for hours exposed to a very high temperature. The heat of the body does not in these instances rise above 100° , owing to the great evaporation or perspiration taking place at the surface of the skin. Hence, a dry atmosphere, by promoting evaporation, enables a much higher temperature to be endured than a moist one.

The young of man, as well as of all animals, do not possess so great a power as the adult of resisting alternations of temperature. This is especially true as regards their power of resisting cold. It is thus a matter of great importance that, during cold weather, children should be warmly clothed. The same remark also applies to old persons, for in them the different vital processes are carried on slowly, so that they require assistance from various artificial aids, both warm clothing and external heat, in order to keep up the temperature.

CHAPTER XI.

THE FOOD.

IN order that no evil effects may result to the body from the waste or loss that is continually taking place in it during the respiratory and the other important processes that it performs, it is necessary that a regular and constant supply of fresh material be added to it, for the purpose of renewing those parts that are worn away. The new material is furnished by the food.

To man is accorded the privilege of drawing his food from a greater variety of sources than is possessed by the rest of the animal creation. Most animals possess the power of eating only one particular description of food. Thus, one great class lives only on *materials* derived from the vegetable kingdom, from

which they are called herbivorous or graminivorous; others again eat only the flesh of animals, hence they are called carnivorous. Man, however, owing to his capabilities of living upon both descriptions of food, has been called omnivorous. He is enabled thus widely to draw the materials for his support, partly through the structure and arrangement of his digestive organs, and partly through this circumstance, that, by his intelligence, he can, by cooking, reduce substances of an apparently hard and indigestible nature to a condition in which they can be readily absorbed, and rendered fit for the nourishment of the body. It is from this power of drawing his food from so wide a range of substances, as well as of resisting great changes of temperature, that man can live in so many different regions.

In whatever country he is placed, he can always maintain life upon the description of food found there; and further, the edible materials naturally existing in any country are always the best adapted for the food of those that inhabit it.

Kinds of Food.—Numerous as the substances are that we eat, and apparently diverse in their composition, yet they may be reduced to three or four great classes :—

× 1st. Those in which there is a preponderance of saccharine matters, or of substances that, by the process of digestion, can be converted into sugar.

2d. Those in which oleaginous or fatty matters form the chief element.

3d. Those in which there is an excess of albuminous matters, —that is, of substances containing nitrogen as an important element in their composition.

These three classes are generally described under the name of the organic materials of food.

We have already seen, however, in the chapter on the Blood, that certain salts and other inorganic matters form an essential feature in its composition. These also must be supplied by the *food, in which they are found in combination with one or other*

of the great classes above mentioned. The inorganic constituents are sometimes regarded as a fourth class.

To these four classes must be added water, which, whether taken pure, or in combination with various vegetable and animal substances, forms such an important part of our daily nutriment.

The saccharine group contains, in addition to sugar, the different varieties of starch, such as exists in bread, rice, sago, potatoes, and other farinaceous substances. Sugar is readily dissolved and absorbed into the system, but starch requires to be subjected to the action of certain of the digestive fluids before it can be rendered soluble. By the action of these fluids, it is converted into sugar. When in the blood, the saccharine materials are principally employed in the combustion which forms such an important part of the function of respiration. This group of substances is derived exclusively from the vegetable kingdom. The different members of the group are composed of the elements carbon, hydrogen, and oxygen.

The oleaginous group is derived partly from the vegetable, and partly from the animal kingdom. It consists of the various vegetable oils, of the fat of animals, and of the yolk of the egg. Like the saccharine, it plays an important part in the respiratory process—its elements, carbon and hydrogen, undergoing oxidation during that process. Like the saccharine group, the different substances composing it do not contain any nitrogen; hence these two groups have been sometimes classed together as the non-nitrogenous constituents of our food.

The albuminous group is perhaps the most important. It is derived both from the vegetable and animal kingdoms. The element, the presence of which essentially characterizes this group, is nitrogen; and, in addition, nearly all the members of the group contain sulphur and phosphorus. Various names are given to the various members, according to the source from which they are derived. Thus, in wheat and other kinds of grain, the albuminous constituent is called gluten; in vegetables, like the pea and bean, legumine; in cheese and milk, casein;

in the white of egg, albumen ; in the flesh and blood of different kinds of animals, albumen and fibrine. This group owes its importance to this circumstance, that after it is received into the blood, it is applied to the nourishment of the nervous and muscular tissues—tissues which play such an essential part in the animal economy. As the albuminous group constitutes so large and important a part of the blood, the substances composing it have been described under the name of the sanguineous or blood-making elements of nutrition ; whilst the oleaginous and saccharine groups, being principally employed as agents in the process of respiration, have been classed together as the respiratory elements of the food.

Since the different groups thus subserve different purposes in the economy of the animal, it is necessary that the food should contain a due and proper mixture of these groups, and not be exclusively confined to one of them. All judicious diet scales are founded upon this principle ; for experience has shown that the attempt to live on one of these groups alone, without permitting a proper admixture of the others, is sure to be followed by disease and death. In some of the most generally employed articles of food, two or more of these groups are combined. Thus, bread is composed of gluten and starch ; an egg contains albumen in the white, and fatty matters in the yolk ; milk, again, contains the albuminous principle, casein, the saccharine principle, sugar, and oily matter, butter—the whole being held in solution by water, in which also are dissolved the inorganic salts. In milk, an article of food is provided which, by itself, is capable of supporting life. This is instanced in the young of numbers of animals, whose food for a considerable length of time consists of milk alone. The temperature of the country in which a man lives, and the habits of the individual, influence the proportion in which a mixture of these different groups should be made. Thus, in very cold climates, a large excess of oleaginous matters can be eaten with impunity, nay, appear *absolutely essential* to carrying on the calorific function. In

hot climates, on the other hand, the necessity of taking much fatty matter in the food is almost done away with altogether ; but instead there is a craving for fruit and vegetables, in which the saccharine group abounds,—this group, possessing the same function of affording respiratory elements as the oleaginous, only not to so great a degree, so that it is less heating in its nature. Where the mode of life pursued calls forth a large exercise of muscular or nervous force, then the albuminous group must constitute a considerable proportion of the food, in order to repair the waste that necessarily takes place in the tissues in which those forces are manifested.

Hunger and Thirst.—If the system is not supplied with food at the proper time, then the sensation of hunger is experienced : this is referred to the stomach. If through any cause the supply of liquid is withheld, then thirst is experienced : this is referred to the back of the mouth. The sensations of hunger and thirst, although referred to certain localities especially, yet are expressions, on the part of the system, of the want of a due supply of solid and liquid nutriment. If food be entirely withheld, then starvation is produced, and the individual dies. In death by starvation, the body by degrees wears away, and becomes daily thinner and thinner. The ever-acting respiratory function gradually, yet surely, burns up the combustible part of the body. All those storehouses of fat which may have been accumulated in various parts, are, step by step, consumed ; and when, finally, through their exhaustion, all the proper materials of combustion being consumed, the parts most essential to life, such as the blood, the nervous and muscular tissues, begin to be acted upon, then death rapidly takes place.

The length of time that life may be supported without taking food does not appear to be more than a week. If, however, small quantities of drink be taken, even plain water, existence may be prolonged for a few days longer.

CHAPTER XII.

ORGANS AND PROCESS OF DIGESTION.

SUCH are the materials that are required by the body in order to assist its growth, or to maintain in a state of efficiency those parts that are continually being worn away in the performance of its various duties. It will now be necessary to inquire into the agents, or apparatus, by means of which these various substances are reduced to a state in which they may be absorbed into the blood, and assimilated to the composition of its different parts; for the greater part of the articles used as food are not, even though they have been in the first instance cooked, in a state in which they can be directly absorbed into the blood.

Mastication.—The food is, in the first instance, placed in the mouth. If in the fluid state, it is at once swallowed; if in the solid form, it must be reduced to the state of pulp. This is effected through the instrumentality of the Teeth. The teeth fixed in the lower jaw are raised and depressed by the action of the muscles of mastication moving that jaw, so that the food is pressed between them and the corresponding teeth in the upper jaw, a lateral movement being at the same time communicated to the teeth in the lower jaw, so that the food is, as it were, triturated or ground between the opposing surfaces of the teeth. The tongue, lips, and large muscles of the cheek assist materially in this process of mastication, for they press upon the food, so as to retain it between the grinding surfaces of the teeth.

At the time that this is going on, a large quantity of fluid, the Saliva, is poured into the mouth.

The saliva is formed in the large glands called parotid, placed in front of the ear, Fig. 1, 1, and submaxillary, 2, and sublingual, *lying under the tongue*, 3. It passes from these glands through

the tubes or ducts, 4 and 5, which, commencing by one extremity in the substance of the gland, open by the other into the cavity of the mouth. The formation or secretion of saliva is continually going on, so as to keep the interior of the mouth moist; but during the period of mastication, the secretion of this fluid is greatly increased in quantity. The mere thought of food, especially to a hungry man, produces an increased flow of saliva, causing "the mouth to water." As the saliva flows into the mouth, it becomes mingled with the food, softens it, and thus materially assists the teeth in reducing it to a state of pulp. The secretions of the above-named glands are not, however, the only fluids poured into the mouth; for beneath the whole extent of the soft, moist, mucous membrane lining this cavity, are a number of small glands, the secretion from which aids materially in reducing the food to a pulaceous mass.

The teeth, which are the chief agents in the trituration of the food, vary considerably in number at different periods of life. In early infancy, they have not appeared above the gums, for at this period they are not required—the infant drawing its supply of nutriment, in the fluid form, from the milk of the mother.

At about the seventh or eighth month the teeth begin to penetrate the gums; this gradually going on to the age of three years, when the first set, or milk teeth, are completed. These teeth are twenty in number—ten in each jaw.

Between the age of six and seven, the milk teeth begin to decay, loosen, and gradually drop out; the permanent set of teeth at the same time appearing, and taking the place of the temporary teeth. The eruption of the permanent teeth continues to the age of from twenty to twenty-five, when it is completed by the wisdom teeth, which are the last in projecting through the gums. When the process is completed, the permanent teeth are thirty-two in number—sixteen in each jaw.

Fig. 2 affords a view of the permanent teeth. They have received the following names:—The four front teeth, *a*, are called *incisors*; the pointed tooth on each side of these, *b*,

canine; the next five teeth on each side, *c*, molars;—but the last has had the special name of wisdom tooth given to it,—so that in each jaw there are four incisors, two canines, and ten molars. Of the teeth, the incisors, from their sharp, knife-like edges, are designed for biting or cutting the food. The canines, the upper pair of which, popularly called the eye teeth, are larger than the lower, are much less developed in man than in dogs and other carnivorous animals, in whom they are especially adapted for seizing their prey, and tearing it to pieces. The molars and wisdom teeth are the true grinders; their broad crowns, and the irregular character of their surfaces, eminently fitting them for bruising and crushing the food.

Each tooth is divided into three parts—the crown, the fang, and the neck. In Fig. 3, *e* represents the crown: this is the part that projects above the gums into the cavity of the mouth; *f* represents the fang: this is the part by means of which the tooth is fixed in the hollow or socket in the jaw. Each canine and incisor only possesses one fang, but the molars and wisdom teeth have either two or three fangs. The neck, *g*, is the part where the crown and fang join. The gum closely surrounds and embraces the neck. The crown of the tooth is covered by a white, extremely hard substance, called the enamel, *h*, which, owing to its being with difficulty acted upon by any of the materials taken into the mouth as food, assists most effectively in preserving the crown from injury. The fang of the tooth is covered by a thin layer of bone-like substance, called tooth-bone, *i*. The great mass of the tooth is made up of the substance called dentine or ivory, *k*. This passes upwards into the crown, and downwards into the fang. It contains in its interior a cavity, *l*—the pulp cavity. The whole of the substance of the dentine is permeated by a large number of canals, *m*, which open by one extremity into the pulp cavity, from which they extend to the outer part of the dentine.

Each tooth has a nerve and artery passing to it, and a vein coming from it. These enter the pulp cavity through a hole, Fig. 2

and 3, *z*, in the bottom of the fang, and then run upwards to the top of the cavity. It is by exposure or irritation of the nerve in the pulp cavity of the tooth that the pain of toothache is produced.

Deglutition.—The food is now in a state fit for swallowing. At the commencement of the act of swallowing—deglutition, as it is termed—the bolus of food is collected upon the upper surface of the tongue, 6, the tip of which is pressed against the roof of the mouth. By the contraction of the muscles of the tongue, the bolus is forced backwards through the opening at the back of the mouth into the pharynx, 7. The muscles forming the walls of the pharynx, 8, now contract, and press the bolus downwards into the esophagus or gullet, 9, the muscular fibres of which, in their turn, contract so as to force it into the stomach, 10. As the food passes through the posterior opening of the mouth, it is lubricated by the secretion formed in the tonsils, 11, one of which is situated on each side of this opening. The mouth is not the only cavity opening into the pharynx, for it communicates also with the respiratory passages, both the nose and larynx. It is an object of great importance to prevent, during the act of deglutition, any portion of food passing upwards into the nose, or downwards into the larynx or wind-pipe. A special apparatus is provided, by which this is guarded against. Every time that we swallow, the soft, pendulous palate, 12, at the back of the mouth, is raised and brought in contact with the wall of the pharynx, so as to form for the time being a complete partition between the posterior openings of the mouth and nose. Sometimes, as when laughing during the act of swallowing, the soft palate does not act properly, and then the food, especially if it be in the liquid form, returns through the nose. The upper opening of the larynx is guarded by a valvular body, called the epiglottis, 13, which, for the most part, is erect, so as to allow air to pass freely from the mouth into the wind-pipe in the act of respiration; but during swallowing it is depressed, and, as seen in the figure, completely covers the orifice of the larynx. If through any circumstance this valve

should not act properly, the food would pass into the wind-pipe, and death by suffocation would be produced.¹

Action of the Stomach.—The food having thus reached the stomach, the muscular fibres in its walls contract, so as to move the food about from one end of the stomach to the other, causing it to perform this revolution several times. At the same time a quantity of fluid, the gastric juice, is poured out from numerous small openings in the inner surface of the stomach. By the movements of the food, this fluid becomes thoroughly mixed with it, and converts it into a semi-fluid material, called *chyme*.

In Fig. 4, we have a view of the interior of the stomach, the anterior wall having been removed. The whole of the inner surface is lined by a smooth mucous membrane, in which are seen the numerous small openings through which the gastric juice is poured. In Fig. 5, these openings are seen greatly magnified. Each of these openings leads into a small pit, from which several fine tubes pass. These tubes are lined by a number of very minute particles or cells, represented in Fig. 6 very highly magnified, in which the gastric juice is formed. The walls of these tubes have ramifying upon their exterior a fine network of capillary blood-vessels, from the blood flowing along which these cells possess the power of forming the gastric juice. It is by the bursting of these cells, or by its transudation through their walls, that this fluid becomes discharged into the cavity of the stomach. The distension of the stomach by the food causes its anterior part to be raised upwards against the under surface of the diaphragm, 14. This, to some extent, interferes with the descent of this muscle during inspiration; so that, after taking a full meal, active and violent exercise is always difficult to perform, for the free action of one of the most important of the inspiratory muscles is impeded.

¹ In the figure, the pharynx has been forcibly drawn to one side by the hook, in order to give a view of the parts above described. The respective relations of these different openings with their protecting valves is seen to greater advantage in Plate VIII., Fig. 15.

The food is prevented passing out of the stomach until it is properly chymified, by the contraction of the muscular fibres at its smaller or pyloric end, Fig. 1 and 4, 15. These form a circular valvular constriction around this part of the stomach, which is relaxed at intervals as the chymification of the food gradually becomes completed.

Action of the Intestine.—The chyme now enters the Small Intestine, in the upper part of which, called the duodenum, 16, it becomes mixed with the bile secreted by the liver, 17, and the fluid secreted by the pancreas, 18. It is gradually propelled by the contraction of the muscular fibres in the walls of the duodenum into the other parts of the small intestine, viz., the jejunum, 19, and ileum, 20. The mucous membrane lining the inner surface of the small intestine, presents myriads of minute orifices on its surface. These orifices lead downwards to fine tubular depressions, seen in Fig. 7, *a a*, called the glands of Lieber-kühn, after their discoverer. These glands are lined by minute particles or cells, similar in shape to those lining the glands of the stomach, represented in Fig. 6. Through the action of these cells upon the blood flowing in the capillaries on the outside of each Lieber-kühnian gland, a fluid is secreted, which is poured into the canal of the intestine during digestion, and which becomes, by the movements of the bowels, thoroughly mixed with the chyme. Through the agency of this fluid, together with the biliary and pancreatic fluids, the *chyme* is converted into *chyle*. As the chyle flows along the small intestine, there are separated from it all those portions which are to be employed in the nourishment of the body. The residue, or refuse portion, passes into the large intestine, 21, to be excreted from the system.¹ To the canal, commencing at the mouth and terminating at the end of the large intestine, along which the food or aliment passes, the name of alimentary canal is given. The muscles moving the walls of

¹ In the figure, a portion of the large intestine passing transversely across the abdomen, so as to unite the two parts figured 21, has been cut away, in order to show the duodenum and pancreas, which lie behind it.

this canal, and consequently moving the contents also, from the esophagus down to the large intestine, belong to that division of the muscles which is called *involuntary*, for the will has no power over them,—the stimulus exciting them to contraction being the food contained in the canal, the walls of which they assist in forming.

The Peritoneum.—The whole of the objects above described, lying in the cavity of the abdomen, are covered by a smooth membrane, called *peritoneum*, which passes from these viscera to the back of the abdomen, so as to connect them to it; and through these connections they are prevented, to any great extent, from falling out of their proper positions. The peritoneum in fat persons has large quantities of fat deposited between its folds, especially in the process, 22, which depends from the lower margin of the stomach. This, in the figure, has been almost entirely cut away, but in the natural state it forms a sort of pendulous apron in front of the small intestines. As the diaphragm, 14, moves downwards and upwards in inspiration and expiration, it necessarily causes the viscera of the abdominal cavity to change their places along with it; and as the walls of the stomach and intestine contract, for the purpose of forcing onwards their contents, a certain amount of movement necessarily takes place in them. To guard against any evil effects that might be produced by the movements of these viscera, they are invested by the smooth peritoneal membrane, which also lines the interior of the walls of the cavity in which they lie. The surface of this membrane is lubricated by a moist fluid, which allows these different objects to move upon each other without injury.

CHANGES TAKING PLACE IN THE FOOD IN THE ALIMENTARY CANAL.

We have now seen that the food, in its passage along the alimentary canal, becomes mixed with various fluids in different *parts of the canal*. These fluids induce important changes in it,

so as to render it fit to be absorbed. These changes we will now consider.

Action of the Saliva.—It has already been shown that during mastication a large quantity of saliva is mingled with the food. This partly serves the mechanical purpose of softening it, but it also exercises an intimate or chemical effect upon certain portions of it; for it assists in causing the conversion of the farinaceous or starchy part of the food into the saccharine, changing it from an insoluble to a soluble state, and thus putting it in a condition in which it may be absorbed.

Action of the Gastric Juice.—In the stomach, the food is subjected to the action of the gastric juice, secreted by the mucous membrane of that cavity. The formation of this secretion is not constantly going on, for during the intervals of digestion none is poured into the cavity of the stomach. As soon, however, as food is introduced, a larger quantity of blood passes to this organ, the secretion of the gastric juice rapidly takes place, and considerable quantities of it are poured forth into the cavity of the stomach. This fluid possesses many peculiar properties, one of the most remarkable of which is its acid character, so that to the taste it is quite sour.

The gastric juice exercises a most powerful effect upon certain only of the constituents of the food, not upon all,—those that it most especially acts upon being the class we have already described as the albuminous constituents. Under its influence, meat softens and dissolves. The white of egg, if swallowed raw, is first coagulated, and then dissolved; if swallowed cooked, it is first softened, and then dissolved. Milk, when swallowed, coagulates, owing to the separation of the caseine or cheesy portion from the other constituents. This coagulating or curdling power of the gastric juice, is taken advantage of in the manufacture of cheese; for the *rennet* which is employed for this purpose is nothing more than the mucous membrane of the digestive stomach of the calf. All the experiments and observations that have been made upon the action of this juice on the

farinaceous and oleaginous constituents of the food, lead to the belief that it exercises little or no influence upon them.

The amount of gastric juice secreted during any digestive act does not appear to be proportioned to the amount of food taken, but to the amount of nutriment required by the system at the time for its support; so that, however large a quantity of food be eaten, only so much is dissolved by the gastric juice as the absorbents will take up;—the rest passes onwards in an undissolved condition. It is thus a matter of great importance to eat no more than is absolutely required for the nourishment of the body; for if an excess of food is continually being taken into the alimentary canal, although at the first it may excite no inconvenience, yet ultimately it will produce serious derangement of this portion of the system. The length of time required by the stomach to convert the food into chyme depends upon the nature of the food that has been eaten. As a general rule, it may be stated that animal food requires a less period of time for digestion than vegetable, whilst it undoubtedly contains, in a given bulk, a much larger amount of nutriment than the same quantity of vegetable food. Hence animal food is much more stimulating than vegetable. A diet founded exclusively upon it would ultimately lead to great derangement of the digestive organs. From which arises the necessity of always mixing with our food a proportion of vegetable matters. Rich, highly concentrated soups, are not, as Dr Beaumont has shown, easily digested; for, before the gastric juice can act upon them, the fluid part must be absorbed. The residue is so small, that it cannot be properly acted upon by the muscular contractions of the stomach. Hence, when these descriptions of food are eaten, a certain amount of solid matter should always be taken at the same time.

The stomach should always be emptied of one meal before a second is taken. The length of time required for this depends upon the nature and quantity of the food eaten, and also to a *considerable extent* upon the health and habits of the individual.

A strong, healthy, and active person will digest much more rapidly than a delicate or sedentary individual. Under most circumstances, it may be stated, that during the day not more than an interval of five hours ought to elapse between the different meals.

Action of the Pancreatic Fluid.—In the duodenum, or upper part of the small intestine, the alimentary matters are subjected to the action of the pancreatic and biliary fluids. The pancreatic fluid is secreted by the large gland, called Pancreas or sweet bread, Fig. 1 and 4, 18. This gland lies behind the stomach. The secretion formed in its interior is collected into a tube or duct, which opens into the middle of the duodenum. The fluid secreted by this gland is very similar to that of the salivary glands, and probably exercises a similar influence in the digestion of the farinaceous constituents of the food.

Action of the Bile.—The bile is secreted by the large and important gland called the Liver, Fig. 1, 17, and Fig. 8. This gland is situated in the upper part of the right side of the cavity of the abdomen, its upper surface being in contact with the under surface of the diaphragm, 14. The leading peculiarity of this gland is owing to this circumstance, that all the blood that has passed to the stomach and intestines, both small and large, instead of directly entering the vena cava, is collected into a vein called the portal vein, which enters the liver. The portal vein also receives the blood from the large organ, the spleen, Fig. 1 and 4, 23.

The portal vein, Fig. 8, *o*, enters the liver through a fissure on its under surface, and immediately breaks up into branches, which become smaller and smaller, until they form capillaries. These capillaries gradually collect together again, so as to form the large vein, called the hepatic vein, *q*, which opens into the inferior vena cava, *p*. Thus the blood returning from the alimentary canal, although for a time diverted from the inferior vena cava, yet eventually reaches it. A diagrammatic view of this is given in Plate 5, Fig. 7. A small artery, *r*, the hepatic

artery, also passes to the liver, for the purpose of conveying the blood that has to nourish it, for the liver is not nourished by the blood flowing through the portal and hepatic veins. Filling up the spaces between the capillaries of the portal veins are a very large number of minute microscopic objects, the secreting cells of the liver. In Fig. 9, they are represented highly magnified. These cells lie in close contact with the capillaries, and it is by their agency that the bile is separated from the blood. Each cell contains in its interior minute drops of bile; after a time the cell bursts, and discharges its contents into the fine commencement of the bile duct. The numerous small bile ducts gradually converge, so as to form one large duct, *s*, which leaves the liver at the transverse fissure. This duct, Fig. 4, *s*, may be seen entering the duodenum along with the pancreatic duct. As the bile is only required during the period of digestion, and as the secretion of the bile from the portal blood takes place at other times than the digestive period, a reservoir has to be provided to contain it until such times as it may be required. This is furnished by the Gall-Bladder, 24, which communicates by means of a small duct with the bile duct. The gall-bladder has in its walls involuntary muscular fibres, which, when the bile is required for digestive purposes, contract, so as to force it into the intestinal tube.

The separation of the bile from the blood is not the only important function performed by the liver, for it is in this gland that the sugar is formed which plays such an important part in the function of respiration. For it has been found that the blood of the hepatic vein—that is, the blood leaving the liver—always contains an appreciable amount of sugar. With regard to the uses of the bile in digestion, there is considerable difficulty in forming a correct opinion. It appears to possess the power of checking any tendency to fermentation or putrefaction in the food as it passes along the intestinal canal. Thus, when the secretion of the bile is not *properly going on*, and there is consequently a deficiency of

this fluid in the intestine, certain putrefactive changes probably take place in the food, which produce some forms at least of that most Protean malady, indigestion. The presence of bile in the intestine appears to stimulate generally the functions of this canal, partly by promoting the secretion from the glands and partly also by exciting the contraction of its walls.

Action of the Intestinal Secretion.—The amount of secretion produced in any single intestinal or Lieber-kühnian gland is only small; yet, when the great length of the small intestine is considered, amounting to about twenty feet, and the close manner in which these glands are packed together along its entire extent, it must be obvious that the combined secretion of the whole must be considerable. As it is not possible to collect this fluid, its use cannot be ascertained very well by experiment; but it has been conjectured that, along with the pancreatic fluid and saliva, it assists in rendering soluble the farinaceous part of the food. It is also probable that, together with the pancreatic fluid, it assists in the absorption of fatty matters, by saponifying them, or converting them into an emulsion, which can be readily taken up by the absorbents.

CHAPTER XIII.

ABSORPTION.

ABSORPTION FROM THE DIGESTIVE CANAL.

As the alimentary matter can only be applied to the nourishment of the body after it has been received into the blood, it will be necessary, in the next place, to consider the mode in which it passes from the digestive canal into the blood-vessels. This may take place in two ways,—either through the agency of the capillary blood-vessels, which ramify beneath the mucous

membrane of the stomach and intestines; or by a special set of vessels, called absorbing vessels, which, under the name of *lacteals*, arise in the mucous membrane of the small intestine.

Absorption by the Blood-Vessels.—The capillaries lying beneath the mucous membrane of the stomach, Fig. 5, *p*, possess the power of absorbing from the alimentary matter contained in the cavity certain of its constituents. Thus water, and any substances which it may hold in solution, readily and rapidly pass into the blood-vessels of the stomach; so that when a draught of water is swallowed, it at once enters the circulation through the capillaries of the stomach, without ever passing into the intestines. The capillaries of the intestines also share with those of the stomach in this power of absorbing fluids. If the intestinal mucous membrane is examined, a number of fine processes may be observed projecting from it into the intestinal cavity. These processes, called villi, are represented considerably enlarged in Fig. 7, *b b*. In the interior of these processes the blood-vessels form a fine capillary network, *c*, which possesses a considerable absorptive power. In Fig. 7 only the blood-vessels in two of these processes are represented, yet they exist alike in all. The materials over which the blood-vessels especially exercise an absorptive power, are water, and those substances which it may contain in solution, such as salts, odorous and saccharine substances, together with small quantities of fatty and soluble albuminous substances. The absorption of fluids by the blood-vessels takes place most rapidly when the stomach or intestines do not contain any solid matter. Their absorption is also facilitated in those instances where the capillaries are not greatly distended with blood. All the materials absorbed by the blood-vessels from the alimentary canal, before passing into the stream of the general circulation, necessarily pass through the liver by the portal vein. In this organ those important changes take place which result in certain of their constituents being converted into sugar, and

in the separation from them of those substances which compose the bile, as has already been described.

Absorption by the Lacteals.—The elongated villous processes, Fig. 7, *b b*, contain, in addition to the capillary blood-vessels, a fine tube, which, under the name of lacteal, possesses the power of absorbing certain of the alimentary constituents. Each villus possesses a fine lacteal, represented at *d*. This lies in the centre of the villus; the blood-vessels, *c*, on the other hand, are situated close to the wall. It is a difficult matter to make out how the lacteal begins. Some physiologists have represented it, as in the figure, as formed by the junction of a number of fine rootlets; others, however, regard it as arising by a dilated end. Each lacteal passes down to the base of the villus, and there becomes connected to the lacteals proceeding from the adjacent villi, so that by their junction comparatively large vessels are formed. These leave the intestine, and pass to the back of the abdomen, within the fold of peritoneum, which retains the intestine in its position.

In Fig. 10 a small portion of intestine, *e*, is seen with the lacteals, *d*, leaving it, and passing to the back of the abdomen. There they congregate together, so as to form a large vessel, which, under the name of thoracic duct, *f*, extends upwards along the back of the chest, reaches the root of the neck on the left side, and opens into the venous system at the junction of the large jugular and subclavian veins, *g*. Each villus has upon its outer surface a fine layer of cylindrical particles, Fig. 7, *i*.

As the chyle passes along the small intestines, the process of absorption commences; the fine particles upon the surface of the villus swell up, so as to assume the appearance represented at *k*, owing to the passage of chyle into their interior. From these particles the chyle passes into the villus, causing it to become distended, and appear as if its upper extremity was filled with a number of oil drops. The chyle then enters the lacteals, and through these fine tubes it is conveyed to the thoracic duct and the great veins in the neck, in the manner already described. The chyle

having entered the veins, flows along with the blood to the right auricle of the heart, where it becomes mixed with the blood proceeding from the other parts of the body. Thus in a very short time it becomes diffused throughout the whole circulatory fluid.

The length of tube along which the chyle has to go, from leaving the intestine to entering the blood, enables certain important changes to take place in it, which adapt it in its constitution to that of the blood, and render it more fitted to be mixed with that important fluid. One of the most remarkable of these changes is the appearance in the chyle of a number of small corpuscles, similar to the white corpuscles of the blood. The chyle has a white, milky appearance; and as it enters the lacteals, the extreme transparency of their walls allows this milky colour to be seen through them, from which circumstance they have received the name of lacteal vessels. The lacteals share with the blood-vessels in the power of absorbing the albuminous and saccharine parts of the food; but in addition they also possess the power of absorbing the fatty constituents, the fat having been previously reduced to a state of the most minute division through the agency of the pancreatic and intestinal secretions. The presence of these extremely minute fatty particles communicates to the chyle its milky appearance.

ABSORPTION BY THE BODY GENERALLY.

The power of absorption is not exclusively confined to the blood-vessels and lacteals of the digestive canal. All the soft tissues of the body that are permeable to fluids, appear, to some extent at least, to possess this power.

Amongst these may be named the skin. Lying immediately beneath the skin, in the different parts of the body, are a number of fine vessels, which are called lymph vessels, or lymphatics. These are represented in Fig. 10, *ll*. They are very small, *and are not readily seen, unless they have been previously*

filled with mercury, when they assume the beaded appearance represented in the figure. In their course, they extend upwards to the trunk, and on their way they always pass through one or more bodies called lymphatic glands, *m, m, m*. They are most abundant beneath the skin, but a few lie deeper, accompanying the chief artery of the limb, as seen in the left arm and leg of the figure. These also pass upwards to the trunk, and through one or more lymphatic glands. Having entered the trunk, the great majority join the thoracic duct, *f*. The fluid they contain is thus mixed with the chyle from the lacteals, and with it enters the venous system at *g*. Those that do not join the thoracic duct, open, by means of a distinct duct, into the veins on the right side of the neck at *n*.

There are numerous instances recorded which show that the skin does possess the power of absorbing fluids. Thus, if the whole body be immersed for a time in a bath of warm water, it is found to undergo an increase in weight, even although, during this period, a considerable evaporation of watery vapour has been taking place from the surface of the lungs. And experience has shown, in the case of shipwrecked sailors, that immersion of the body, or only a part of it, in sea water, has checked, for a considerable time, the torments of thirst. This is to be accounted for, partly by the absorption of the skin, and partly by the hinderance which the immersion necessarily places upon the evaporation which would otherwise take place from the surface of the skin. The absorption is effected, partly by the lymph vessels above described, and partly by the capillary blood-vessels, with which, as we shall afterwards see, the skin is most abundantly supplied.

The function of the lymph vessels does not appear, however, to be confined to the mere process of absorption from the surface. For this, it must be remembered, is not constantly going on, but is only required in certain exceptional instances.

These vessels are really for the purpose of assisting in certain intimate changes which are continually taking place in the body.

itself. For it has been supposed, that during the process of nutrition, a larger quantity of fluid is poured out from the capillaries than the tissues actually require for their support. This excess is taken up by the lymphatics, and through them conveyed to the great veins, where it mixes with the circulating fluid, so that it can be again employed for the purposes of nutrition. Another and perhaps more probable supposition is, that, as the tissues wear away, certain of their constituents, although no longer adapted for the nutrition of the particular tissue they proceed from, yet may perhaps be applied to the nourishment of other tissues. These constituents the lymphatics absorb.

It has already been mentioned, that the lymph vessels always pass through one or more of the bodies called lymphatic glands, in which certain changes are induced in the lymph which render it more fitted to be mixed with the blood. Through similar glandular bodies the chyle, after being absorbed by the lacteals, also passes, in which those changes, which have already been described as taking place in it, probably occur. It will thus be seen, that all the materials which enter the blood pass through certain glandular organs before they are allowed to do so. Thus the lymph and chyle pass through the lymphatic glands; the substances absorbed by the blood-vessels of the alimentary canal, through the liver. In these glands, these different materials undergo certain changes which render them more fitted for being mixed with the circulating fluid.

There are other glands in the human body which appear to exercise modifying influences upon the whole mass of the blood itself. The most important of these is the spleen, 23. These are all connected with the great end and object of the blood, viz., to render it fit and perfect for the nutrition of the body.

CHAPTER XIV.

NUTRITION AND SECRETION.

WE have seen, in the previous sections, that, during the life of the body, certain changes are constantly taking place in it, which would result in its decay and death, if means were not taken to counteract this tendency. It is by the food that we daily eat, that those materials are supplied, which repair the losses that are continually going on. The process by which the constituents of the food—after they have undergone digestion and absorption—are applied to this purpose, is called the function of

NUTRITION.

Nutrition is not, however, to be considered merely as the process by which the adult body, after being once formed, is maintained and kept in an efficient state. It must also be regarded as playing a most important part in the development of the body; that is, in the changes which take place in its embryonic state, so as to elevate it to its proper typical position in the organised world. It is by the operation of this process also that the body grows, or has materials added to it, by which it increases in size.

The blood, and the blood alone, is the fluid by which the various nutritive materials are conveyed throughout the whole system. And in order to insure that this may be done effectually, the whole body is traversed by the numerous tubes or vessels which we have already considered under the names of arteries, capillaries, and veins. With one or two exceptions, every tissue is permeated by numbers of fine capillaries. Even the very hardest structures, such as bone and teeth, have these small *blood-vessels passing into their interior.*

In Plate I., Fig. 5 and 6, *a* represents the Haversian canal containing one of these fine blood-vessels. Surrounding this canal are the spaces called lacunæ, with their connecting canaliculi, which, although too small to contain a blood-vessel, yet readily allow the nutritive fluid exuded from the blood to traverse them.

In Plate VI., Fig. 3, are seen the blood-vessels passing upwards into the cavity in the centre of the tooth. From these vessels a nutritive fluid is poured out which traverses the fine system of tubes, *m*, in the dentine or ivory. From the nutritive fluid in the lacunæ and canaliculi of a bone the materials necessary for the nutrition of the bone are selected, and applied to the purpose either of increasing its size, or of making good any loss that may have taken place in it. From the nutritive fluid passing through the dentine tubes, the different structures of the tooth select those materials which may be required for their nutrition. The enamel, the tooth bone, and the dentine, each taking unto itself the substances best adapted for its support.

In Plate III., Fig. 3, the capillaries, *d*, are represented lying between the fibres of a muscle. From the blood flowing along these the muscle selects those constituents which, in the progress of growth, or in the active exercise of its functions, it may require.

In a similar manner the other tissues are traversed by these fine blood-vessels. The number of capillaries in a part are, as a rule, proportioned to the changes taking place in that part. It must be obvious that the more active the functions of a part are, the greater will be the changes that occur there, and the greater, consequently, the amount of blood required by the part. Hence all those tissues which, like muscle, are continually active, contain a large proportion of capillaries, and are, as it is termed, very vascular. Bone and teeth, which, from the great abundance of inorganic matter they contain, are called the hard tissues, undergo comparatively a small amount of change, so that the *proportion of blood-vessels to the other constituents is limited.*

Each tissue possesses the power of selecting those materials from the blood which approach most nearly to its own composition. Thus, in the case of the bone and teeth, the salt, composed of lime and phosphoric acid, is selected, and in a similar manner with the other tissues. The withdrawal of these different substances from the blood is not to be regarded as a mere passive transudation through the walls of the capillaries. There can be no doubt that it depends upon a positive attraction, exercised upon them by the tissues through which the blood is flowing; this attraction being co-existent with the life of the part, and ceasing when life ceases. This attraction has been already incidentally mentioned in the description of the movements of the blood. For it is supposed that it possesses, to a small extent at least, the power of drawing the blood onwards, and thus assisting in promoting the circulation. It has been spoken of under the name of *vis a fronte*, and is very different from the active propelling power of the heart, which is a *vis a tergo*.

It has been clearly pointed out by Mr Paget that certain conditions are essential to the proper performance of the function of nutrition. By the derangement of any one of which serious mischief would arise in a part. Amongst these the following are the most important :—

1st. That the part receives a proper and due supply of blood, and that this blood contains those materials necessary for the nutrition of the part. For if the access of blood to a part, or of those materials only which it specially requires, be cut off, it necessarily dies.

2d. That the blood be in a healthy state. This is a most essential condition, for if the material supplied be not healthy, it cannot be expected that the part will be efficiently nourished.

3d. That the part itself be in a healthy state. For if it is not so, the vital affinities between the blood and the tissues are no longer exercised, so that the requisite materials for its nutrition are not poured into it.

4th. That the nerves passing to a part be in a healthy state,

and that their connection to the great centre in which they arise be perfect. For it has been found that if the large nervous trunks passing to a limb are cut through, there is considerable danger of the death of the limb occurring.

SECRETION.

Closely allied to the function of nutrition is that of secretion.

By this term is signified the separation from the blood of the peculiar principles, which have to be formed and elaborated by the different glands of the body into their special secretions.

In the various parts of the body numerous glands are found which secrete fluids of diverse compositions, and destined for different purposes.

Thus, along the course of the alimentary canal we have already met with the salivary glands, which secrete saliva; and with the pancreas, liver, and various intestinal glands, each of which pours into the digestive canal its own special fluid. All of these secretions assisting in the process of digestion. In the skin, again, there are numerous glands which form the fluid called the sweat; and in the kidneys we have glands by which the special secretion of the urine is separated from the blood.

All these glands are abundantly supplied with blood-vessels, which form in their numerous networks of capillaries, from the blood flowing along which the secretion of the gland is formed. The separation of the secretion from the blood, or the formation of the secretion by the principles supplied by the blood, takes place through the agency of small bodies, which have been called cells. Examples of these are figured in Plate VI., Fig. 6 and 9. Every gland contains numbers of these cells, which may possess different shapes. The cells in each gland separate and elaborate the secretion of that gland. When the elaboration is completed, the cells burst and discharge the secretion. All glands consequently possess a duct or tube, along which their *secretion may flow to the part to which it has to proceed.*

The power by which each gland draws from the blood the materials adapted for the formation of its own special secretion, is similar to that by which each tissue obtains the materials best adapted for its own nutrition. It depends upon the vital or elective affinities of the gland.

The glands exercise most important duties in the animal economy ; for they not merely supply fluids which are destined to serve various purposes in the economy—such as the secretions poured into the alimentary canal—but they also separate from the blood, principles which, if allowed to remain in it, would exercise a most injurious effect. Thus if, through any cause, the function of a gland is interfered with, the special secretions of that gland remain in the blood. If it is an important one, such as the liver or kidney, then very dangerous symptoms are produced. 7

CHAPTER XV.

GENERAL PROPERTIES OF NERVE TISSUE.

THE various functions which we have been describing in the foregoing sections, under the names of circulation, respiration, and digestion, are all subservient to the great process of nutrition.

For the proper regulation of this process the body is provided with a Nervous System, which exercises a controlling and directing agency, not only over the function of nutrition, but also over all those processes which are connected to it.

The nervous system has, however, a higher purpose than that of being merely the regulator of these functions. For through it the Mind is made conscious of the objects existing around it, and by its agency the Will reacts upon these objects, as when it puts in action the muscles of locomotion.

If the structure of this system be looked into, it will be found to be *divisible into two* distinct tissues : one, in which the colour is

grey, ranging from a light grey to a dark brown, and hence called the grey matter; the other, in which the colour is white, hence called the white matter. These differences of colour depend upon differences of structure, which can only be properly made out by the aid of the microscope, when strong magnifying powers must be employed.

Nerve Cells.—The grey matter is then found to consist of collections of cellular bodies, called nerve cells or nerve vesicles. These cells commonly present processes branching from them, as in Fig. 2, *a*. The *processes*, called the *poles* of the cell, are not always so numerous as in the cells represented in the figure; sometimes there is only one, at others two, and in other instances several. The names of unipolar, bipolar, and multipolar have been given to these different modifications of cells. Each cell contains in its centre a well marked spot called the nucleus, around which a number of dark-coloured granules are grouped. It is upon the presence of these granules that the grey colour of this kind of nerve tissue is due.

The white matter does not contain any nerve cells. It consists of a number of fibres, arranged in a parallel direction, called nerve fibres or nerve tubes.

Each of these nerve tubes is divisible into certain parts. Thus, the outer part consists of a white material, called the white substance of Schwann, *b*, after its discoverer; whilst the interior, or axis of the fibre, is of a somewhat darker hue, and is called the axis cylinder, *c*. Investing the exterior of each tube is a fine membrane, *d*, which keeps the contents of the tube together. These contents are soft, and readily pressed out of the tube when it is cut across, so that they may form a bulging at the extremity, as at *e*, in the figure.

The nerve cells do not lie indiscriminately scattered about amongst the nerve fibres, but are grouped together in greater or less abundance in certain localities. These groups of cells are called *Nerve Centres*.

Nerve Fibres.—The nerve fibres constitute what are called

the nerves of the body, that is, the white cord-like objects met with in examining the various parts of the body. Each nerve consists of fibres running parallel to each other; the number of these fibres being proportioned to the thickness of the nerve.

Every nerve is connected by one extremity to a nerve centre; by the other extremity it is connected to one or other of the tissues. Thus, some nerves are connected to the skin, others to mucous membranes, others to muscles, others to the different viscera, and similarly to the other structures.

The inquiry into the mode in which the extremity that enters a nerve centre terminates, is one of considerable difficulty. Hence, at different times, various opinions have been entertained by physiologists upon this question. But the tendency of modern investigation leads to the belief that every nerve fibre, entering a nerve centre, terminates by joining a nerve cell; the elongated processes, or poles, proceeding from the cell, becoming continuous with the nerve fibre. This is shown at *f*, Fig. 2. It will be observed that, as the junction between the two takes place, the nerve fibre loses the outer portion of its structure, which we have described under the name of the white substance of Schwann; the part of the fibre that becomes continuous with the cell being the central axis. The processes proceeding from the nerve cells are not solely for the purpose of connecting them to the nerve fibre, but, as may be seen at *g*, in the figure, also for connecting the different cells to each other.

The two components of the nervous system, described as nerve cells and nerve fibres, possess very different functions. Those collections of nerve cells, which we have already mentioned under the name of nerve centres, undoubtedly possess a much higher function than the nerve fibres, for it is in certain of them that the faculties of sensation and perception are seated; and they all, undoubtedly, possess the power of originating or reflecting nerve force. They are also the localities in which the mental acts manifest themselves, and by means of which voluntary and involuntary actions are induced in the system; these being induced

by that peculiar modification of force residing in the nervous system which has been called nerve force.

The principal collections of nerve cells are found in the Brain, 1, and Spinal Cord, 2; from which circumstance they are the great centres for the origination of nerve force.¹

The nerve fibres, on the other hand, are mere conductors of this nerve force, they possess no power of originating it. For this purpose of conduction their structure eminently fits them. The conducting part of the fibre is the central axis. Now, as all the fibres in any given nerve run parallel to each other, it is probable there would be a danger of the nerve force, instead of passing continuously along each fibre, becoming transmitted to the adjacent fibres, and so lost. To counteract this, the central axis is surrounded by the white substance of Schwann, the function of which appears to be to act as an effectual isolating material, so as to confine the force to the fibre along which it is travelling.

An illustrative comparison may be made between a bundle of nerve fibres and an electric cable. In the cable there are a number of copper wires, each surrounded by a coating of gutta percha, or other insulating material, so that the electric currents, which are travelling along the copper wires, are protected from lateral dispersion owing to the non-conducting material surrounding each wire. In a nerve fibre the central axis may be compared with the copper wire, the white substance of Schwann with the gutta percha. Nerve fibres do not branch in their course, but at their terminations, in certain structures, they have been observed to break up into extremely minute filaments. From their origin in a nerve centre they extend continuously and unbroken to the part to which they are distributed, however distant that may be from the centre.

Although all the nerve fibres possess the same structure, and are all capable of conducting nerve force, yet certain differences are to be observed in them respecting the direction in which this force

¹ *In this Plate, where the same letters or numbers are employed in the different figures, they are intended to represent the same object.*

is conveyed ; the kind of structure to or from which a nerve proceeds, appearing to regulate entirely the function of that nerve, and the direction in which the nerve force passing along it is conveyed. Thus, certain fibres appear only to possess the power of conducting nerve force from the surface to the centre. By the action of this force in the brain are induced those changes by which the mind becomes acquainted with the properties of bodies ; whether these be communicated through the structures inducing touch or common sensation, or through the special organs which induce the sensations of light, sound, flavour, and odours. The nerve fibres through whose agency sensations are excited, are called *sensory* fibres, and as they convey nerve force to the centre they are also called *centripetal* nerve fibres.¹ There are other centripetal nerve fibres, however, which, although conveying nerve force to the centre, yet do not cause the mind to perceive any sensation ; for these fibres do not pass upwards so far as the brain, but terminate in the spinal cord, or some of the smaller nerve centres. They are connected to the motor fibres through the medium of the nerve cells, and through this connection they are enabled to excite or induce movements in the muscles. They have been called *excito-motor* fibres. There are fibres, again, which convey nerve force in exactly the opposite direction, that is, from the centre to the parts to which the nerves are distributed. They are principally distributed to the muscles. It is through the force conveyed by them that the muscles are induced to contract or move. They are called *motor* or *centrifugal* fibres.² The different fibres described under the above-mentioned names, lie in the greater number of nerves, parallel to each other, and so exactly alike that it is impossible to distinguish one kind from

¹ Centripetal, from *centrum*, a centre, and *peto*, to seek. Because the force that they conduct has a tendency to pass from the surface or periphery in which the fibre terminates at one extremity, to the centre in which it terminates at the other.

² Centrifugal, from *centrum*, and *fugo*, to fly from. Because the force is conducted away from the centre.

another. The nerves proceeding from the organs of special sense are, however, exclusively composed of sensory fibres.

CHAPTER XVI.

CEREBRO-SPINAL NERVOUS AXIS.

HAVING now considered the general properties of nerve tissue, we will proceed to describe more in detail the different divisions of the nervous system. The first and most essential are the nerve centres. The great nerve centres of man and all other vertebrate animals are the Brain, 1, and Spinal Cord, 2. These occupy the cavities in the interior of the skull and spinal canal, and they are closely connected together. From them, as a centre or axis, the various nerves either converge or diverge, so that they have been described under the name of cerebro-spinal nervous axis.

Spinal Cord or Spinal Marrow.—We will, in the first instance, inquire into the structure and functions of the spinal cord. This term is, in the strict sense, limited to that part of the nervous axis which occupies the spinal canal. It extends from the upper end of that canal to about the level of the first vertebra of the loins, below which it terminates by coming to a fine-pointed extremity. It does not occupy the whole length of the spinal canal; for the lower end of the canal is filled by the large nerves which proceed from an enlargement found on the cord in the region of the loins, just before it terminates, as may be seen in the figure. Continuous with its upper extremity is the body called *medulla oblongata*, 3, which, although lying in the cavity of the skull, yet so closely corresponds with the cord both in structure and function, that it is better to consider them together. The *medulla oblongata* is larger than the cord, and appears to form its *upper extremity*. The cord itself, however, does not possess the

same diameter throughout, for it swells out in the regions of the neck and loins. This is owing to a number of large nerves being connected to it in both those regions. Both the cord and medulla are divided into two lateral halves by a fissure on their anterior and posterior surfaces. Each half consists both of grey and white nervous matter; the white matter being on the surface, so that the grey is concealed by it. Hence the conducting part of the cord is outside that portion of it which acts as a nerve centre.

The most interesting circumstance to inquire into respecting the structure of these bodies, is to ascertain the mode in which the different nerves attached to their sides are prolonged into their interior. Connected to each side of the spinal cord are thirty-one nerves, springing from corresponding points on the two sides, so that they constitute thirty-one pairs. They pass out of the spinal canal through the foramina or holes which exist between the different vertebræ. Every nerve is attached to the side of the cord from which it springs by two distinct roots. Each root consists of a number of distinct fibres. These are represented in Fig. 3, and as one root is placed in front of the other, they are called anterior, *h*, and posterior, *i*. Upon each posterior root a swelling or ganglion, *j*, is found, which contains nerve cells. Through this ganglion the fibres of the posterior root proceed. The fibres of the anterior root join those of the posterior beyond the situation of the ganglion. Every nerve is thus composed of an intimate mixture of the fibres proceeding from both anterior and posterior roots.

The fibres of both roots enter the spinal cord. Their exact course in the cord, and their mode of termination, has long been one of the most interesting questions in the whole science of anatomy. The delicacy of the structures entails great difficulties upon their examination. Various opinions have consequently, at different times, been advanced by eminent inquirers, but there has always been a difficulty in reconciling their statements with what is known respecting many of the functions of the cord.

During the last two or three years, the inquiries of several anatomists have thrown a new light upon this question.

Fig. 4 is a diagram which will illustrate the idea that has been arrived at by these researches into the structure of the cord and the mode of termination of the nerves in it. It consists of a vertical section through the cord from the anterior, *h*, to the posterior, *i*, nerve roots on one side. It will there be seen that, when the anterior nerve roots enter the cord, they connect themselves immediately to the nerve cells, *k*, situated in that part of the cord which they enter. In the diagram only one fibre of each anterior root and only one nerve cell are represented for the sake of simplicity, but all the fibres of this root must be regarded as joining nerve cells in a similar manner.

The fibres of the posterior root, *i*, on the other hand, appear to consist of two distinct sets, of which one, immediately after entering the cord, ascends, *l*, and passing upwards through the medulla, most probably becomes connected with the grey matter in one or other of the divisions of the brain. The other, however, passes considerably forwards, *m*, and joins the nerve cell to which a fibre of the corresponding anterior root has proceeded; at least, such is the most simple way of viewing it. But there are reasons for supposing that, instead of at once joining this cell, it is connected to a nerve cell at its own side of the cord, which, through its elongated processes, is closely connected to the motor nerve cell. For, although only one cell has been figured, yet the grey matter in the interior of the cord, and consequently the nerve cells, are in considerable abundance. Thus the nerve roots on the same side of the cord are brought into communication through the agency of the nerve cells. In a similar manner the nerve cells on opposite sides of the cord communicate, so that the nerves constituting each pair are, to a certain extent, brought into relation with each other. The diagram also represents a long filament, *n*, extending upwards from the anterior nerve cell.

This ascends through the anterior part of the medulla, and connects the anterior nerve cell with the brain. Thus each nerve

root is to be regarded as in communication with the brain, through the agency of the spinal cord and medulla: the posterior root directly through the filament that passes from the root directly upwards; the anterior root not directly, but through a filament proceeding from the nerve cell with which it is continuous.

These various longitudinal filaments are clustered together in different parts of the cord; those belonging to the posterior root being situated in the posterior part of each lateral half, constituting what is called the posterior column; and those belonging to the anterior root, in the anterior part of the same half, forming the anterior column. The spinal cord is thus seen to be made up of numbers of nerve fibres and nerve cells. The great majority of the fibres extend in the longitudinal direction, and are for the purpose of connecting, either directly or indirectly, the nerve roots with the brain. The nerve cells connect the different nerve roots to each other.

The spinal cord is consequently both a conductor and originator of nerve force. Before considering its function, however, it may be as well to say a few words respecting the distribution of the numerous nerves proceeding from it.

Spinal Nerves.—These nerves almost correspond in number to the vertebræ, between which they pass in their course outwards. They present, in different parts of the trunk, different arrangements; the most simple, and consequently the typical form, being seen in their course in the region of the chest, 4. Here each nerve passes directly outwards in the space between the ribs as far forwards as the breast-bone, becoming gradually smaller in its course, for it sends off filaments in its passage to the muscles occupying the intercostal space and the skin over it. In the regions of the neck and loins, however, the nerves are arranged in a more complex manner; for it is from these parts that the nerves going to the extremities proceed. Instead of pursuing a straight course, the nerves, in these different regions, come together, so that their fibres are intermingled one with the other. These are called *plexuses*. From the two plexuses in the neck,

5 and 6, the nerves proceed which pass to the arm. These come more especially from the lower one, 6, which is much larger than the upper. It is called the brachial plexus. The nerves which arise from the lower part of the spinal cord also form two large plexuses, 7 and 8, from which the nerves that pass to the legs proceed. By the intermingling of the nerve fibres which takes place in these plexuses, the branches proceeding from them are brought into connection with a greater extent of the cord than they would have been if no such intermingling had taken place. The various large nerves going to the arm, pass some on the outer side, others on the inner, others in front, and others behind. In their course they give off numerous branches, of which some enter the muscles, and others pass to the skin. Some of the nerves are continued down as far as the tips of the fingers; these are called the digital nerves, 9. The upper of the two plexuses, from which the nerves of the leg proceed, sends off two branches which pass to the thigh, more especially the large nerve, called anterior nerve of the thigh, 10, which gives off numbers of branches both to the muscles and skin. From it also a large branch, 11, proceeds, which is distributed to a part of the skin of the leg. The lower one supplies the back of the thigh and the remaining part of the leg and foot, especially through the large nerve, which, under the name of sciatic, 12, extends down the back of the thigh. It divides just above the ham into two large branches, which supply the muscles and the greater part of the skin of the leg. Some of these branches may be traced downwards as far as the toes, along the sides of which, under the name of digital nerves, 13, they extend.

In the left leg of Fig. 1 a view is given of the various structures that enter into the composition of a limb. 14 represents the muscles attached to the bones for the purpose of moving them. These are retained in their position by the strong fascia, 15. Lying beneath the fascia is the large artery, 16, which conveys the blood for the purpose of nourishing the different structures. The greater part of this vessel continues beneath the

fascia for the purpose of supplying the muscles ; but a few small branches, 17, perforate the fascia, in order that they may pass to the skin. 18 represents the large vein of the limb which accompanies the artery. It is joined by the large superficial vein, 19 ; and through it the blood is conveyed away from the limb. 20 represents the lymphatics placed beneath the skin and lying upon the fascia. 10 is the large anterior nerve of the thigh passing to supply the important extensor group of muscles on the front of the thigh. From it branches proceed, 21, which perforate the fascia, in order that they may reach the skin in which they terminate.

Functions of the Spinal Cord and Nerves.—As the spinal nerves are all intimately connected to the cord, and as their functions cannot very well be separated, we will consider them together. We will suppose that a part of the body, such as the skin, in which sensory nerve fibres terminate, touches any object, certain changes are induced in the touch organs which puts in action the nerve force. This is conveyed by the sensory fibres of the nerves proceeding from these organs along the nerve to that part of the cord to which the fibres proceed. It enters the cord, not by both roots, but only by the posterior ; for numerous experiments have shown that the posterior root alone is capable of conducting that kind of nerve force which is capable of inducing a sensation. It thus reaches the posterior part of the cord, and is at once conveyed upwards along the posterior column to the brain, when the sensation is perceived. Should the mind be now desirous of putting in action the muscles so as to lift the object, or otherwise move it, then the motor nerve filaments convey to the muscles the nerve force which is capable of inducing their contraction. This passes from the brain down the anterior columns of the cord as far as the part from which the nerves proceed that supply the muscles that have to be moved. It then leaves the cord along the anterior nerve root ; for this root alone is capable of conveying nerve force to muscles. The impression next travels along the nerve to the muscles that have to be brought into

action. This passage upwards to the brain of the nerve force which induces a sensation, and downwards to the muscles of the nerve force which induces motion, which we have described in detail, takes place almost instantaneously, and in many cases with scarcely a moment's interval between the mind's perceiving a sensation and acting upon it. Recent observations, however, have shown that the rate of passage of the nerve force along the nerve is a perfectly definite one, so much so, that it is capable of being measured. By tracing the course of the various large nerves to the different muscles, the anatomist has discovered that the bundles of filaments, collected together in a large nerve, are distributed, as a general rule, to those muscles which, being grouped together, possess the same action. Thus, the large nerve on the front of the thigh, 10, supplies all those muscles which straighten the leg. On the other hand, the muscles which bend the leg are supplied by a different nerve, the sciatic, 12. So that muscles whose actions are opposed to each other, receive their nervous supply from different sources.

In order to excite the movement of muscles, it is not necessary that the motor impulses should, in all instances, originate in the brain. The spinal cord itself, through the agency of the nerve cells, possesses this power. This is especially shown in those cases where, through disease or injury, the connection between the brain and cord is separated. Suppose that this has occurred above the origins of the large nerves passing to the arms or legs; then, by no effort of the will can any of these extremities be moved, for the conduction of the impulse is stopped by the division of the conducting fibres. But suppose the skin of any of these parts be now irritated by a stimulant, the impression is conveyed to the cord along those fibres which enter it at the posterior root, under the name of excito-motor fibres. These, instead of ascending towards the brain, terminate in the nerve cells of the part of the cord in which they enter. Through the agency of these cells, with which the motor fibres also communicate, an impression is conveyed or reflected to the motor

fibres, by which the action of the muscles in the limb is excited. This function of the cord is described as its reflex function. The mode in which the reflection from the sensory to the motor fibres takes place, through the intervention of the nerve cells, may be understood by referring to the diagram, Fig. 4. What the changes are that take place in the cells, by which an impression is transmitted from one fibre to another, are not known. They are probably due to the excitation of that peculiar power or force to which the name of nerve force has been given. In all these cases, when the reflex function of the cord is brought into operation, the impressions are never conveyed as far as the brain, so that the mind is not made cognizant of them.

Experiments show, that in whatever part of their course the sensory fibres in a large nerve are irritated, the same sensation will be produced. This sensation, although only perceived in the brain, is yet referred, not so much to the part at which the irritating or stimulating agent is applied, as to the part where the nerve is distributed. An example of this is afforded by the well-known sensation popularly called "pins and needles." This is produced by sitting for a length of time in the same position, so as to press upon the sciatic nerve. At first, no inconvenience is felt; but, after a time, peculiar pricking sensations are perceived, which are referred to those parts of the foot and leg to which the sensory fibres of this nerve are distributed. If this pressure be kept up for some time longer, a temporary paralysis of the sensory fibre is produced, so that the leg and foot lose all power of sensation or feeling, and they are then popularly said to be "asleep." Another striking example of this reference of sensations to the parts to which a nerve is distributed, is afforded by pressing upon what is called "the funny bone." This so-called "funny bone" is really a large nerve, which, under the name of ulnar, passes down by the inner side of the elbow-joint. Now, when pressure is made upon it, the tingling or pricking sensations are referred to the innermost fingers, and the inner side of the skin of the fore-arm; that is, to the parts to which its sensory fibres are distributed.

Nerves of the Medulla Oblongata.—Attached to each side of the medulla oblongata are several large nerves, which differ from those connected to the spinal cord in this important particular, that they have only one root. We have already seen that the spinal nerves are compound nerves; that is, composed both of sensory and motor fibres. The nerves arising from the medulla are, however, simple nerves, either sensory or motor, or both, according as their root springs from the posterior or anterior part of the medulla alone, or receives filaments from both sources.

The nerves of the medulla present a greater relative importance in the economy than those of the spinal cord. Those of the latter, govern merely the ordinary sensations and movements of the individual; but those of the former, govern certain special actions, which, if not properly performed, would result in certain death. Thus, from the medulla arises that large nerve which, from the length of its course, has had the name of *vagus* or *wandering nerve* given to it, 22. It extends down the side of the neck, to be distributed to the gullet, stomach, heart, lungs, and organ of voice. This is a sensory nerve at its origin; but in its course it receives some motor fibres from an accessory nerve, 23, which join it.¹

By the branches it sends to the gullet, Fig. 5, 24, it induces those movements which, under the name of movements of swallowing, result in the propulsion of the food into the stomach.

By the branches it sends to the stomach, 25, the movements of that organ, so necessary to the proper performance of the process of digestion, are regulated.

Through the branches it sends to the heart, 26, it governs the contractions of this organ, causing them to be performed in a regular and constant succession.

Through the branches, 27, it sends to the lungs, the nerve centre is made aware of the necessity that exists for respiration.

¹ See especially Fig. 3, where an enlarged side view of the medulla is represented.

This impression is reflected in the medulla to the motor fibres that act upon the muscles of respiration, so as to excite their regular and continuous action. One of the most important of these motor nerves is the large nerve, 28, which, under the name of phrenic, runs down from the upper plexus in the neck in front of the lung to the diaphragm. All these various movements, both of the stomach, of swallowing, of the heart, and the lungs, take place involuntarily ; that is, without there being any necessity to call into action the will in order to produce them. This is of the greatest consequence, for they are all processes essential to the continuance of life. And it is required of them, that they should go on in all states and conditions of the mind—whether it be free and unoccupied, or engaged in some absorbing pursuit, or unconscious of all external impressions, as in sleep.

The filaments that it sends to the organ of voice, or larynx, are also very important ; for the nerve is not only distributed to the muscles which regulate the voice, and which close and open the aperture of the glottis, but it also contains the sensory filaments, which proceed from the mucous membrane lining the interior of the larynx. This is a very essential circumstance. For if, in the act of swallowing, any portion of the food, instead of passing down the esophagus, enters the upper orifice of the larynx, the sensory filaments of this nerve are excited so as to induce in the nerve centre, *i. e.*, the medulla, a sensation which, being reflected to the motor fibres of the nerve, puts in action the muscles of the glottis so as to close it, and prevent the further downward passage of the food.

Arising also from the side of the medulla, is the important nerve, 29, which regulates the movements of the muscles of the tongue ; and springing from it, close to the vagus, is the nerve, 30, through which the special sense of taste is transmitted to the medulla.

Taking its origin also in this part of the nervous axis, is the large and important nerve concerned in the function of hearing, 31, by which auditory impressions are conducted.

The Brain.—This is the largest and most important of the nerve centres. It occupies the large cavity of the cranium or skull. It is divided into several portions: the Cerebrum or great brain, 32; the Cerebellum or little brain, 33; and the Pons or bridge, 34. The medulla oblongata, from being situated in the cranial cavity, is often considered as one of its divisions, but that we have already described with the spinal cord.

The cerebrum, or brain proper, is divided into two lateral halves or hemispheres by the fissure, 35; the hemisphere on one side being an exact repetition of the opposite one. So that the cerebrum is to be regarded as a double organ, possessing exactly corresponding parts on the two sides. Each hemisphere is subdivided into three lobes: anterior lobe, 36; middle lobe, 37; posterior lobe, 38. Each hemisphere is composed partly of grey matter or nerve cells, and partly of white matter or nerve fibres. The grey matter is in large quantity, the principal collection of it being upon the surface; the whole of the exterior of the hemispheres having a peculiar appearance from the manner in which the grey matter is arranged. Thus it will be seen to present a tortuous and convoluted arrangement, whence the name of convolutions of the brain has been given to it. These convolutions are separated from each other by depressions, which extend for varying distances into the substance of the brain. The convoluted arrangement evidently affords a much greater extent of this kind of nerve tissue, than if the surface had been quite smooth and uniform. A comparative examination of the brains of different animals shows, that the more highly organized a brain is, the more convoluted is its exterior; for, as we ascend in the scale, the convolutions become more and more numerous, and occupy a larger surface. Thus, the brain of man, who possesses the greatest intelligence, is the most convoluted. The deposits of grey matter are not, however, confined to the surface of the brain, for there are several distinct collections in the *interior*. These are situated at the base or lower surface of the *cerebrum*. Different names have been given to them, but they

may be classed together as the great Sensory Ganglia at the base of the brain. Connecting these different collections of nerve cells with each other are numbers of fine white fibres. Some of these unite the different deposits on the same side, so that the ganglia at the base are connected together, and each of these is again connected to the great deposit of grey matter on the convoluted surface. Not merely, however, are the collections of nerve cells in one hemisphere connected together; but, through similar white fibres, they are also intimately united with the corresponding deposits in the opposite. These connecting white fibres are called the commissures of the brain. Through their agency the nerve force is conveyed from one nerve centre to the other; and by them the two hemispheres are so intimately connected together, that their consentaneous action is insured. In addition, numerous fibres can be traced passing upwards from the spinal cord and medulla, through the pons, to the different nerve centres in the cerebrum. Along these the nerve force, which has been transmitted to the cord and medulla by their nerves, are conducted to the brain; and along these also the manifestations of the will are transmitted down the medulla and cord, to pass by the motor nerves to the muscles.

The cerebellum, like the cerebrum, is divided into two hemispheres by a fissure. Each hemisphere consists both of grey and white matter. The surface is composed of grey matter, which is not convoluted, but arranged in a laminar manner, like the leaves of a book. Deposits of grey matter are also found in its interior. The white fibres of the cerebellum connect the different deposits of nerve cells with each other. The two hemispheres are also connected by numerous white fibres which pass across the pons. This body lies like a bridge between these hemispheres, whence its name. The cerebellum is also connected by white fibres above with the cerebrum, and below with the medulla and spinal cord.

The pons consists both of grey and white matter; the white matter being on the surface. It is principally composed of the

white fibres extending upwards from the medulla to the cerebrum, and of the white fibres connecting the two hemispheres of the cerebellum.

Cranial Nerves.—The cerebrum and the pons have several large and important nerves connected to them. There are none, however, attached to the cerebellum. Those springing from the cerebrum and pons are connected to their under surface or base, and their fibres may be traced into their interior for a short distance, when they are found to be connected to some of the deposits of nerve cells or ganglia at the base of the brain. Of these nerves, some are conductors of the nerve force which induces special sensations, as the nerve of smell, 39, and the nerve of sight, 40. Connected also to the side of the pons is the nerve of hearing, 31; but this may be traced backwards to its origin in the nerve cells of the medulla. There are three small nerves, 41, also on each side, which regulate the movements of the eye-ball.

The consideration of the functions of these nerves falls more properly under that of the senses to which they belong, so that we shall leave them for a time. At present we shall confine ourselves to the nerves which pass to the face.

Two large nerves on each side go to the face. Of these one, 42, is for the purpose of being distributed solely to the muscles, filaments entering each of the small muscles of this region. It is, consequently, a motor nerve. Through it the nerve force is conveyed to this region, so as to put in action one or more of these small muscles. The other nerve, 43, has a different distribution altogether, and consequently a different function; for it passes to the skin, and is thus a sensory nerve. It divides into branches before arriving at the face, so that it reaches it in three distinct localities, 43, Fig. 5. Numerous branches then pass to the different parts of the skin. This nerve is not merely distributed to the skin; but it also supplies numerous filaments to the mucous membrane lining the mouth and surface of the *tongue, nose, and front of the eye-ball*. Through these filaments

all sensory impressions made on these parts are conveyed to the brain. Some time before reaching the face, this nerve gives certain filaments to the muscles of mastication. These differ from the other parts of the nerve in this respect, that they are motor and not sensory filaments; for through them the nerve force, which sets in action those muscles, is conducted. These motor filaments arise by a different root from that which gives origin to the sensory filaments. The sensory filaments exclusively make up the great mass of the nerve. Those portions of it, however, which contain motor filaments also, constitute a compound nerve. It is described by anatomists under the name of the fifth nerve.

The brain and spinal cord, as they lie in their bony chambers, are not placed in direct contact with the bone, but are separated from it by certain membranes. Of these the one lying next the bone is the strongest. It lines continuously the whole extent of the cerebro-spinal cavity. It may be seen at 49, Fig. 6. Closely investing the exterior of the brain and spinal cord, is a thin membrane, in which the blood-vessels ramify before they enter the interior of these organs. Covering this vascular membrane and lining the inner surface of the strong membrane, 49, is an extremely delicate serous membrane. These membranes protect the highly delicate nervous substance of which these organs are composed. A small quantity of fluid is always found in the interior of the cranial cavity and spinal canal, in close contact with the brain and cord. It is for the purpose of protecting them from vibrations or jars, which, in the various movements of the body, might otherwise be communicated to them.

Functions of the Cerebellum.—The cerebellum is a portion of the brain, respecting the functions of which there has been, at various times, great differences of opinion amongst physiologists. The great majority, however, from a variety of considerations, deduced from experiments performed on it, and observations on the effects of disease upon it, are inclined to consider that this organ possesses the power of regulating the movements of the

muscles, or of co-ordinating them, as it has been termed. By this is meant, the faculty of calling into operation the actions of different groups of muscles for the performance of a given object. Some of the principal evidence in favour of this view is derived from the fact, that in animals that are in the habit of moving rapidly, or that require several groups of muscles to be in action at the same time, this organ is largely developed in proportion to the rest of the brain. Man, who from the multifarious duties he is called upon to perform, and from the great precision with which most of his muscular movements require to be executed, certainly requires some organ to co-ordinate or regulate these movements. In him the cerebellum is largely developed in proportion to the size of the brain. This power is called into operation through the fibres which, on the one hand, connect the cerebellum to the cerebrum; and, on the other, the cerebellum to the spinal cord. In confirmation of this opinion, numerous instances have been observed in which, owing to disease of this organ, the muscular movements have been disturbed and irregular. It must be confessed, however, that over the functions of this organ considerable obscurity exists; so that, although there are many reasons for regarding it as possessing the power of co-ordinating muscular action, yet it probably has other functions. What these may be physiologists have not as yet been able to discover.

The recent discoveries in the structure of the spinal cord, by showing the abundant communications that exist between the nerve fibres of the same root, and the fibres of different roots, through the medium of the nerve cells, would appear to indicate that the cord itself must also possess considerable influence over the co-ordination of muscular movements.

Functions of the Cerebrum.—The cerebrum is the most highly endowed of the various divisions of the brain. It is the organ of the mind, the various operations of which are manifested through it.

In considering its physiology, it is necessary to remember that

the grey matter found in it may be separated into two great divisions ; that found at the base of the brain constituting the sensory ganglia of the base, and that found on the surface constituting the grey matter of the convolutions. Each of these two divisions possesses different functions. In the sensory ganglia the sensory nerves, both those of common and special sensation, terminate ; and it is in them that those sensations are excited which render the mind cognizant of external objects. To these ganglia the motor nerves also have most important connections. It is probable that through the agency of the nerve cells, by which one set of fibres is brought into connection with another, that those changes take place which result in the reflection of impressions from one nerve to another so as to produce instinctive and habitual movements.

The convolutions of the brain possess a much higher function than the sensory ganglia, for it is through them that the higher qualities of the mind are manifested. It has already been mentioned, that they are more numerous in man than in any other animal ; and not only so, but they are much more perfectly developed in the adult than in the child. In those also whose mental powers are of a low order, such as idiots, the size and extent of the convoluted surface of the brain are limited.

These various circumstances all lead to the conclusion, that their office is of a much higher kind than that of any of the other divisions of the brain. Owing to the manner in which the convolutions are arranged on the surface of the brain, it is obvious that the larger a brain is, the greater will be the extent of its convoluted surface ; from which circumstance the conclusion has been drawn, that those who possess large brains will be persons of great intellectual acquirements. Observation, to a certain extent, though not altogether, has confirmed this hypothesis ; for it has been found that most of those who have acquired great influence over their fellow-men—who have been in the true sense rulers—have been large-headed, large-brained men. The size of the head does not, however, always indicate that there

is a large brain within, for there are several circumstances which may tend to produce a large skull without the brain growing in a proportionate manner. In attempting to form, however, an estimate of the extent of the intellectual capabilities from the size of the head, it must be kept in mind that the skull may be large through excessive growth in one direction only ; so that, although there may be great size, yet the head will be badly proportioned ; a well balanced, well proportioned skull, with its contained brain, appearing to be conditions essential to the possession of well regulated mental attainments.

All physiologists agree in the belief, that the intellectual powers are proportioned to the development of the convolutions. The phrenological school has, however, gone further than this. It has attempted to prove that different parts of the convolutions are the seats of the different faculties of the mind, and that these are manifested by an individual in proportion to the degree in which the particular convolutions, or parts of convolutions, are developed. The disciples of this school have also stated, that the shape of the head, in detail, is influenced by the shape of the contained brain ; and, that the size and development of the different parts of the convolutions, produce corresponding elevations or depressions upon the outer surface of the skull ; so that, by examining the exterior of the head, an idea may be formed respecting the size of these different organs, and the extent to which the faculties of which they are the seat are developed in the individual.

Other physiologists and anatomists are not, however, willing to admit all the conclusions to which the phrenologist has arrived ; neither are the mental philosophers prepared to coincide with him in the divisions to which he has reduced the various mental faculties. That different parts of the brain are the seats of different functions is generally admitted, but it still remains a matter of doubt where these various functions are located. Again, there can be no question that the shape of the skull affords, *generally*, a very good idea of the shape of the contained brain ;

but, in some parts of the skull, there are certain modifications of its structure which entirely prevent this from being ascertained. This is especially manifested in the region of the forehead along the line of the eyebrows. In most adult heads there is a considerable prominence along this line, and here the phrenologist has located certain of the faculties into which he divides the mind. But this prominence is not due to a corresponding projection of the brain in this region; it is simply owing to this circumstance, that here the two layers of bone, of which the bones of the head are composed, are separated from each other by a considerable interval, the outer one being pushed forwards in order to afford room for the frontal sinus.

It follows from what has been stated, that every mental act is accompanied by some change in the grey matter of the convolutions. These convolutions must thus be regarded as the seats of those faculties which make up the intellect. But that principle which regulates the intellectual and moral constitution of man—that self-consciousness or higher reason which distinguishes him from the lower animals—cannot be said to have any special seat in the brain, neither are its manifestations due to the organization of the brain.

CHAPTER XVII.

SYMPATHETIC NERVE.

IN addition to the nerves that have now been described, we have to consider a system of nerves which, under the name of sympathetic nerve, plays an important part in regulating the functions of the economy. This nerve can scarcely be regarded as belonging to the cerebro-spinal nervous system; for although many connecting filaments pass between the two, yet it possesses so many independent centres of its own, that it must be regarded

as, to a great extent, a separate system. The complete course of this nerve may be seen in Fig. 1, 44. It is placed at the side of the spinal column, running almost parallel to it. It extends from the first vertebra in the neck downwards as far as the coccyx, in front of which bone the sympathetic nerve on one side joins the one from the opposite. At various points in its course, swellings or dilatations are found, which are caused by the presence of nerve cells in these localities. Each of these swellings is consequently a nerve centre or ganglion. The number of these dilatations nearly corresponds with that of the vertebræ. From these ganglia filaments (45) pass, which connect the sympathetic to each of the different spinal nerves, as they pass outwards through the foramina between the vertebræ. From these ganglia branches also proceed, which are distributed to the various large viscera in the cavities of the chest and abdomen. In Fig. 5 many of these branches are represented, especially those going to the heart, 46, lungs, 47, and stomach, 48. Before the branches pass to those different organs, they interlace so as to form large plexuses, in which interlacement the filaments of the vagus going to the same organs also join. From these plexuses, as from a centre, numerous branches pass to the above named viscera. In Fig. 5, 48 represents the large plexus, from which branches proceed to the stomach and other important viscera of the abdomen.

In conformity with the statement that has already been made, that the part to which a nerve is distributed influences mainly the function of that nerve, we must suppose that the sympathetic nerve regulates the secretions and movements of the various important organs to which it proceeds. Some of these, however, such as the heart, lungs, and stomach, receiving also filaments from the vagus, are not exclusively under its influence. The salivary glands also receive nerves both from the sympathetic and cerebro-spinal systems. Those organs which receive their nervous supply from both systems, appear to be *brought more* under the influence of the mind than those to

which only sympathetic filaments are distributed. This is especially manifested in the cases of the heart and the stomach ; the movements of the former organ being very much influenced by the different states of the mind. Thus, excessive fear may so far disturb its actions as to diminish considerably the force and number of its contractions ; and several well authenticated cases are on record, in which, under the influence of this emotion, its movements have been entirely suspended. Similar disturbing influences are also exercised upon it by the other passions and emotions.

The secretion of the gastric juice appears also to be considerably under the influence of the mind. Thus, it is well known, that one of the best aids to digestion is a happy and contented state of mind ; for here no disturbing influence interferes with the proper secretion of the gastric fluid. But under powerful mental emotions its secretion may be entirely suspended, so as completely to put a stop, for a time, to the digestive process. Hence the loss of appetite that almost invariably accompanies greatly excited conditions of the mind.

There are a class of sensations and actions which, under the name of sympathies, were at one time supposed to be under the governance of this nerve, from which circumstance the name of sympathetic was given to it. These are supposed now, however, to be under the guidance of the cerebro-spinal system ; to these may be referred pain or disturbance of function in an organ, when another organ is not in a proper state of health. A forcible example of this is presented in those cases in which palpitations of the heart are brought on in certain forms of indigestion, owing to the stomach being out of order, and not performing its functions properly.

CHAPTER XVIII.

ON SENSATION.

WE will now proceed to the consideration of those organs, by the agency of which, and the nerves proceeding from them, sensory impressions or sensations are communicated to the mind. These are amongst the most important organs in the body, for it is through their agency that the mind is made acquainted with the various objects surrounding it in the external world. Thus, by the sense of touch, it is enabled to perceive the density of bodies, their comparative hardness, or their temperature. By the sense of sight, it perceives their size, form, and colour. By the sense of hearing, it distinguishes the various vibratory impressions each is capable of producing. By the sense of taste, it distinguishes whether they are tasteless, that is, incapable of exciting the nerve of taste, or whether they cause it to convey an impression which produces in the nerve centre a sense of sweetness or acidity. By the sense of smell their odour is ascertained, either agreeable or disagreeable.

Each of these different senses has a special organ and a special nerve for the excitation of its particular sensation; the shape and arrangement of the organ being especially adapted for the particular sensation to which it is subservient. An important point to be kept in mind is this, that it is not in the organs of sense, as they are called, that these special sensations are perceived; it is in the brain alone that this perception takes place. Each sense organ has thus its special nerve, which conveys to the brain the sensation of which that organ is the agent. Thus, from the papillæ of the skin, the nerves of common sensation or of touch proceed; from the eye the nerve of sight passes; from the ear the nerve of hearing; from the tongue the nerve of *taste*; from the nose the nerve of smell.

Each of these nerves terminates in the brain in a distinct locality, so that it may very reasonably be inferred that the seat of any particular sensation is at the point of termination of the nerve proceeding from the organ in which that sensation is excited. As these nerves all convey impressions to the brain, they are consequently all centripetal nerves. Although a different sensation is excited by each nerve, yet they all possess exactly the same structure; so that we have in this a confirmation of the statement already made, that the function of a nerve is determined by the organs to which it is connected at its extremities.

Every sense organ, with the nerves proceeding from it, is alone capable of exciting its own sensation—those peculiar stimuli which possess the power of exciting any particular sensation only acting through the organ which is set apart for the induction of that sensation. Thus we can only see with the eyes, we cannot hear or smell with them. The skin alone is capable of inducing tactile impressions; it possesses no power of taste. Whatever be the stimulus applied to the nerve of sight, either from its own proper stimulus, viz., the rays of light, or from an electric shock, only sensations of light are perceived by the mind. In a similar manner, whatever be the stimulus that excites the nerve of hearing, only sensations of sound are perceived. And in like manner with the other senses. Each sense organ, being thus confined to its own particular sense, is of course much more perfectly adapted for the production of that sense, than if other sensations had been combined with it.

There are certain parts of the body to which nerves are not distributed at all, or only very sparingly. Hence these structures do not possess any sensibility, or only a small amount. The most important of these structures are the bones, ligaments, and tendons.

It has been found that all parts highly endowed with sensibility also possess a large supply of capillary blood-vessels; the presence of a constantly moving and changing current of blood

being apparently necessary to the proper excitation of sensations.

CHAPTER XIX.

THE SKIN AND COMMON SENSATION.

THE faculty of determining the properties of bodies by the touch resides in the skin. As certain special structures are found in it for the excitation of this sense, it will be necessary, in the first instance, to consider their anatomy.

As the skin, however, is not merely the touch organ, but, from its containing certain accessory structures, possesses also other properties and uses, it will be advisable in this place to consider the various structures by which these are performed.

Structure of the Skin.—The best way of obtaining an accurate idea of the structure of the skin is to make a section through it perpendicular to the surface, and to examine this section by the aid of the microscope. Fig. 7 is a view of this kind.

The skin is now found to be divided into two parts, of which the deeper is called the cutis, dermis, or true skin, *o*; the superficial being termed the cuticle, epidermis, or scarf skin, *p*. The boundary line between the two is well defined. Of these the cutis is the most important.

The surface of the cutis, next the cuticle, is always firmer and more condensed than the deeper parts of the cutis. In the former situation it is elevated into a number of small projections, called papillæ, *q*, which fit into corresponding depressions in the deep surface of the cuticle. By its deep surface the cutis becomes gradually blended with the cellular tissue and fat, which forms a constant layer beneath the skin. Passing upwards into the papillæ are the fine capillary blood-vessels, *r*, from which the blood flows when the skin is cut or pricked. Also extending into the

papillæ are the small nerves of the skin, which join there a peculiar body, called the touch organ, *s*, from its supposed use in exciting the sensibility to tactile impressions. These papillæ are most abundant in those parts of the body which are most sensible to touch, such as the palms of the hands, tips of the fingers, and margins of the lips. A surface view of these papillary projections is afforded at *q*, Fig. 8, from which the cuticle has been removed.

The cuticle consists of a comparatively hard and dense structure lying in close contact with the cutis, and not capable of being separated from it in the healthy and living skin. It is destitute both of blood-vessels and nerves; hence it is utterly devoid of sensibility. It consists of several layers, one being placed over the other. These layers present different appearances in the deep and superficial parts of the cuticle. Each layer is composed of small cellular bodies called epithelium cells, which, in the deeper layers, are globular in shape; but as they are traced to the surface they become more and more flattened, and, at the same time, harder and more horny. These changes are represented in the detached cells at the side of Fig. 7. In the deeper layers of the cuticle the colouring matter of the skin, or pigment, is found. This is much more abundant in the cuticle of the dark races than in that of the fair races of man. The difference between the colour of different skins thus simply depends upon a greater or less amount of deposition of pigment in the deeper layers of the cuticle. Those dark spots, so frequently seen on different parts of the skin, called freckles and moles, are simply owing to increased formation of pigment in those particular localities.

The outer surface of the cuticle, in many parts of the body, especially on the palm of the hand, is marked by ridges and furrows, presenting varying courses and directions. The ridges indicate the position of the papillæ, which, by their projection, push forward the cuticle covering them. The furrows are produced by the sinking in of the cuticle into the spaces be-

tween the rows of papillæ. The thickness of the cuticle varies very much in different parts of the body. This is a consequence of its chief function ; for, owing to its insensibility and non-vascularity, it is for the purpose of protecting the highly sensible and delicate cutis from injury. Hence, in those regions where the skin is frequently exposed to pressure, the cuticle grows very thick and hard, as is especially seen in the soles of the feet. This is most strikingly shown in the formation of corns, which consist of excessive developments of the cuticle on some part of the foot which has been pressed upon for a length of time by a tight-fitting boot or shoe. The difference between a hard and a soft hand also depends upon the greater or less development of the cuticle ; for, in those accustomed to manual labour, the hand becomes protected by numerous layers of the cuticle, which consequently render it hard and horny.

Those peculiar growths which occur on various parts of the skin, but more especially on the hands of children, which are called warts, consist of an enlargement of the papillæ of the cutis at that part. These papillæ are always, however, covered by the cuticle.

Touch or Common Sensation.—The sense of touch resides exclusively in the papillæ of the skin, where the touch organs are found. Amongst the most sensitive parts, are to be mentioned the tip of the tongue, the tips of the fingers, the margin of the lips, and the palm and back of the hand. The arms and legs are much less sensitive than the hands and feet. Of all the parts of the body, the trunk appears to be the least sensitive to impressions. Through this sense of touch, or by feeling, we are enabled to ascertain the forms of different substances. This is effected by gradually passing the hands over them, when impressions are successively communicated to the tactile papillæ, which cause an excitation of the nerve force. This is conveyed along the nerves to the brain, and there perceived, so that an idea is thus formed of the shape of the substance touched. This can be produced by the sense of touch alone, without the assistance

of the eyes. By the touch also we are enabled to ascertain the resistance offered by a substance; and it is thus we can distinguish between a hard and a soft material. In the estimation of this, however, we are partially assisted by what is called the muscular sense. This is a function which is undoubtedly possessed by the muscles, by which the amount of muscular force that is required to be put in action in order to overcome the weight or the resistance offered by any substance is regulated. Differences of temperature are also determined by the nerves of touch. Heat and cold are, however, to be regarded merely as relative sensations, depending upon the temperature of the part of the body applied to the material to be tested. Experience shows that the greater the extent of the surface of the body exposed to changes of temperature, the greater is the effect produced.

In blind persons, in whom the sense of touch has been properly cultivated, it may be made to perform a variety of functions. By it very distinct ideas may be formed respecting the shape and physical properties of bodies, and instances have even been known in which differences of colour have been appreciated.

The Sweat Glands.—Connected to the skin are the peculiar glandular bodies which possess the property of secreting the sweat or perspiration. These are seen in a vertical section of the skin, such as Fig. 7. They consist of a small coiled-up ball of tubing, *t*, which lies in the deeper parts of the cutis. From this ball a tube or duct extends, which passes through the cutis and cuticle so as to open on the surface of the skin, *u*. In its course, this tube pursues somewhat of a corkscrew-like course, and, in its passage through the cutis, it is situated between the papillæ, *v*, Fig. 8. Ramifying on the exterior of the small ball are the capillary blood-vessels, from the blood in which the small cells in the interior of the ball possess the power of separating the sweat.

These glands are extremely abundant in the skin; some parts,

however, possessing them in greater numbers than others. It has been calculated that in the skin of the palm as many as 3528 exist in every square inch of surface, and that throughout the whole body there is an average of 2800 for every square inch of surface. From this, some idea may be formed of the great abundance of these glands.

The secretion of the sweat is constantly going on, although, in ordinary temperatures, and when the body is at rest, it is not perceived, for it evaporates from the surface of the skin as soon as formed. During violent exercise, and in hot weather, this secretion is considerably increased in quantity, and it is then seen collected on the surface of the skin in small drops. Some idea may be formed of the extent of the evaporation which is thus constantly going on from the skin, from the statement that, if the tubes of all the perspiratory glands were joined together, they would measure several miles in length. It is by this evaporation that the temperature of the body is regulated; so that, whatever be the heat of the climate, so long as this function is properly performed, the temperature of the body does not rise above 100°.

A curious relation has been found to subsist between this secretion of the skin and that of the kidneys or urine. If the amount of sweat formed is large, the urine is considerably diminished in quantity; for the blood, losing a certain amount of its watery particles in one direction, cannot afford to part with a large quantity by any other channel. It is this constant draining away from the blood of its water, that entails the necessity of drinking daily a considerable amount of fluid, in order that the loss so sustained may be repaired, and that the fluidity of the blood may be preserved.

If the perspiratory secretion be not removed from the skin, it is apt to dry there, and block up the orifices of the sweat ducts, or pores of the skin, as they have also been called. This would, of course, impede the further pouring out of the secretion, which, *if confined, is liable to produce in the course of time considerable*

mischief. Hence the necessity of daily ablutions, in order to remove from the surface of the skin the dried perspiratory secretion which is constantly collecting there.

CHAPTER XX.

THE NAILS AND HAIR.

IN certain localities the skin has special structures developed in connection with it, which are for the purpose of affording it protection. These are the nails and hair.

The Nails.—These are slightly curved horny bodies, placed at the extremities of the fingers and toes, on their backs or dorsal surfaces. They consist exactly of the same material as the cuticle, which in this locality has become hardened and thickened, in order to protect the highly sensitive ends of the fingers and toes. Every nail rests in a sort of bed, the surface of which is formed of the cutis, which, at the sides and root of the nail, somewhat overlaps it. Thus the nail appears to fit into a kind of groove in the cutis, something like the manner in which a watch-glass fits into its rim.

In Plate VII., Fig. 9, *w* represents the last bone of a finger, *x* is the nail. At *y* may be seen the groove in the cutis into which the nail fits, with a prolongation of the cuticle extending for a short distance over it. The growth of the nail takes place both at its root and also along the whole extent of the under surface where it rests on the cutis. Thus, as it advances forwards, it increases both in length and thickness. The constant cutting greatly facilitates the growth. In those cases in which the nails

of certain Asiatic nations, although in the
attain great length, yet their rate of growth

coming from the surface of the skin are a num-

ber of fine, delicate structures, called hairs. These vary considerably in number and texture in different parts of the body. On the head they are extremely abundant and very delicate in texture, as well as of considerable length. The hairs of the eyelashes and eyebrows are much shorter and stronger. The hairs that are scattered over the greater part of the surface of the trunk and extremities are the shortest and most delicate. On certain parts of the skin no hairs exist at all, as on the palm and sole, the upper eyelids, and the back of the last joints of the fingers and toes. The age and sex of the individual influence greatly the number, size and strength of these projections.

Every hair lies in a depression in the skin called the hair follicle, Plate VIII., Fig. 8, *a*. The depth of this depression varies greatly in different hairs, as may be seen in the figure. It always extends, however, for some distance into the cutis. It is lined by a prolongation of the cuticle, which is continued into it. The follicle expands slightly at its deepest part, and at the bottom of this expansion a small papillary elevation, *b*, corresponding to one of the papillæ of the cutis, is situated. From this papilla the hair springs.

Each hair possesses a root, *c*, and a shaft, *d*. The root being the part lying in the hair follicle, the shaft projecting beyond it and coming to a fine point at its extremity. The root of the hair dilates at its lower end, in order to correspond to the expansion of the follicle. This dilatation is called the bulb of the hair, *e*, and into it the papilla of the follicle passes.

If a hair is examined under the microscope, it presents at first an appearance as if it were hollow or tubular in the centre, but a more careful examination shows that this is not the case. A row of very fine cells extending down the centre; the great mass of the hair consists of a number of minute fibres, closely united together.

The exterior possesses a sort of cuticular investment, the *scales* composing which overlap each other, so as to present an *imbricated* appearance, as at *d* in the figure.

After a hair has existed a certain time, certain changes begin to take place in it. It gradually loses its colour, and becomes grey or white. No fixed period can be precisely stated as to when this may take place, as it appears to vary much in the hairs of different persons and different localities. If an individual is exposed to great mental anxiety, these changes may rapidly take place; and several well authenticated cases are recorded in which the hair turned grey or white in a single night.

Long-continued and intense study appear also to have a tendency to produce discoloration of the hair. It is probable that this is occasioned by the nutritive changes which are necessary for the proper maintenance of the life of the hair being imperfectly carried on.

Hairs also, after a certain time, have a tendency to fall out. This is produced, as in the discoloration of the hair, by defective nutrition, which occasions their death. In the great majority of cases, especially in young persons, the old hair is replaced by a fresh one. This, although not growing from the same papilla, yet projects outwards through the same follicle as the hair that has fallen out. It is supposed that the outward growth of the young hair is the cause of the death of the old one. Baldness is produced when the hairs in a locality die, fall out, and are not replaced by fresh ones.

There are certain circumstances which tend to favour the growth of the hair. Whatever induces the blood to flow rapidly to a part of the skin appears to facilitate the growth of hairs in that part, for it enables their nutrition to be more actively carried on. Hence has arisen the practice of applying stimulating washes or ointments to the hair, for the purpose of encouraging its growth in the locality in which these applications are made. If the hair is frequently cut, its rate of growth is considerably increased.

Observation has shown certain curious circumstances connected with the growth of the hair. Thus it has been found to

grow faster during the day than during the night, and at a greater rate in summer than in winter.

The fact above mentioned, of the growth of the hair being proportioned to the flow of blood in the part, explains these circumstances. For the functions of the skin are much more actively performed by day than by night, and in the summer than in winter.

Great variations, as regards colour and texture, are observed in the hairs of different races of men. It may be stated generally, that the inhabitants of cold northern climates have light fair hair, whilst those who dwell in hotter and more tropical regions have the hair of a dark or black colour. As regards texture, in some, the hair is short, crisp, and curling; in others, it is long and flowing. The Negro presents the best example of short curly hair. The term woolly has been applied to it, but in all its microscopic characters it presents the appearance of a true hair.

The hair is evidently intended to be of service, both ornamentally and for its direct usefulness. Long flowing hair, especially in the female sex, being considered as an element of great beauty. So far as regards its use, it serves to protect the skin, and to contribute materially to its warmth. This is especially seen in many of the lower animals, whose skins are provided with a thick coating of warm hair, which, in them, effectually supersedes the necessity of clothing.

Each hair is provided with a special apparatus for ensuring its being kept always soft, and to a certain extent moist. Opening into the hair follicle are one or more small glands, *f*, called sebaceous glands, which secrete a fluid of a greasy nature, which, passing into the follicle, lubricates the surface of the hair. It is owing to this circumstance that the hairs in their natural state, without the application of any artificial ungent, always possess a more or less greasy feel to the touch.

CHAPTER XXI.

THE TONGUE AND THE SENSE OF TASTE.

CLOSELY allied to the sense of touch is that of taste. The Tongue is the chief organ provided for the excitation of the sense of Taste. It is not, however, the only structure in which this faculty resides. For the various parts at the back of the mouth, especially the under surface of the soft palate, to a greater or less extent, participate in this endowment. Not merely, however, does the tongue possess the power of exciting *gustative* or taste sensations, but it is also highly endowed with the sense of touch. The tip of the tongue possessing, to a greater extent than any other part of the body, the power of common sensation.

In its structure the tongue consists of a large number of muscles, the fibres of which are arranged in a very complicated manner. The greater number of these fibres are connected to a small bone placed at the top of the larynx, called the hyoid, or U-shaped bone, from which they may be said to arise. Hence this part has been called the root of the tongue. It is by the action of these muscles that the various movements of the tongue are performed. Their fibres are so arranged that they can project it from the mouth, draw it back again, and move it from side to side, so as to adapt it in the best manner for the performance of the various functions of taste, touch, mastication, and deglutition, in which it is concerned. The upper surface of the tongue is almost flat and covered by a mucous membrane. This is continued over the sides of the tongue to its under surface, from which it passes to the floor of the mouth, forming a bridle or *frænum* which assists in preventing the too great protrusion of the tongue by the muscles.

The *mucous membrane* on the upper surface is elevated into a

number of projections, called the *Papillæ* of the tongue, which present different shapes in different parts of the tongue. Situated quite at the back of this surface are several large papillæ, which, from possessing a depression around their bases, are called the *Circumvallate papillæ*, Fig. 7, *g*. Scattered over this surface, though most abundant at the sides and tip, are the *Fungiform papillæ*, *h*. The great majority, however, of these elevations, which occupy the intervals between the two last named papillæ, are called the *Filiform papillæ*, *i*. The whole of these papillæ are covered by an epithelium, which, though differing in shape from that investing the papillæ of the skin, yet possesses a similar function, viz., that of protection.

When the epithelium collects in considerable quantity upon the surface, it produces the white appearance to which the name of furred tongue has been given.

Passing to the tongue on each side is a large artery, which conveys blood to it for the purpose of nourishing it. Proceeding from the tongue also are corresponding veins, which convey away the blood after it has fulfilled this office. Fine capillary vessels are found in the papillæ, their arrangement being closely similar to that figured and described in the papillæ of the cutis.

Three large nerves pass to each side of the tongue. Of these, one is distributed to the muscles, 29 ; it is consequently a motor nerve. The other two pass to the papillæ ; these are sensory nerves. They proceed to different parts of the tongue ; one to the front and sides, called the lingual nerve, 43 ; the other to the back of the organ, 30. There is considerable difference of opinion amongst physiologists as to the exact office of these two nerves. Some suppose that the lingual nerve is not the medium for exciting gustative sensations, but is simply the nerve of touch or common sensation. They regard the nerve that passes to the back of the organ as the only nerve of taste. Other physiologists, however, are inclined to the belief that both nerves may be *endowed* with the power of conducting taste impressions. In the *papillæ*, the filaments of these nerves terminate in peculiar struc-

tures, called taste organs, closely corresponding to the touch organs in the skin. It is by the contact of sapid materials with these organs that the sense of taste is excited.

In order to excite the sense of taste, it is necessary that the substances applied to the tongue be either in solution or capable of being dissolved by the fluids of the mouth. For, without this, they cannot penetrate through the epithelium covering the papillæ, so as to come in contact with the taste organ.

The sensibility appears to be most acute at the tip, sides, and back of the tongue. The sense of taste enables us to discriminate between sour or sweet, and bitter or saline, substances. Great numbers of sapid materials possess a considerable odour, as in most aromatic substances. These excite the sense of smell at the same time that they influence the sense of taste, and, by the combined action of these two senses, our appreciation of the flavour of these substances is greatly heightened. The sense of taste may remain in the mouth for some time after the material that induced it has been swallowed. This is owing to the solution of the substance in the fluids of the mouth, which, by collecting about the papillæ, keeps up the particular flavour that has been induced. Experience teaches us that the acuteness of this sense may be considerably diminished by taking some highly aromatic substance; for this will obscure, for a time, almost completely the more delicate flavour of any substance which may be swallowed shortly after.

CHAPTER XXII.

THE EYE-BALL AND THE SENSE OF SIGHT.

THE Eye-ball is the complex special apparatus provided for the reception of the rays of light, previous to the impressions produced by them being conducted to the brain.

Connected with the eye-ball are certain accessory structures,

some of which afford it protection, others being for the purpose of moving it in various directions. These will be considered in the first instance.

Accessory Structures of the Eye-Ball.—The eye-ball is lodged in a large cavity on the side of the face, external to the nose, called the orbit. The upper and lower margins of this cavity are well marked and strong projections. Extending along the line of the upper margin is a thick fold of the skin, containing a considerable quantity of fat. This is the Eye-brow, Fig. 1, 1. The outer surface of this is closely set with short strong hairs. Certain small muscles are connected to the deep surface of the eye-brow for the purpose either of elevating or contracting it. By its movements, under the action of these muscles, great expression can be given to the features—elevation of the eye-brow taking place during surprise or astonishment; contraction occurring during displeasure, as in the act of frowning.

The eye-ball is protected by two moveable shields, called the Eye-lids, 2; one being in relation more especially to the upper surface of the front of the eye-ball, the other to the lower surface. Of the two, the upper eye-lid is most moveable. The elevation of this lid takes place through the contraction of a small muscle placed within the orbit, which, from this circumstance, is called the elevator of the upper eye-lid, Fig. 2, 3. The closure of the lids is produced by the orbicular muscle, represented in the muscular figure at 2. Each lid is strengthened by a thin layer of cartilage contained in its interior. Fringing the margins of the lids are the short hairs called Eye-lashes. Those connected to the upper lid are longer than those connected to the lower. They project also downwards and forwards, so as to overlap a considerable part of the front of the eye-ball, and thus very materially to protect it. Lining the inner surface of each lid is a smooth, moist membrane, called the Conjunctiva, which is prolonged over the front of the eye-ball. Lying on the inner surface of the lid, and covered by the conjunctiva, are a number of *small glandular bodies*, called the Meibomian glands, which

secrete that peculiar waxy matter which collects in greater or less abundance at the roots of the eye-lashes.

The eye-lids, with their depending lashes, are most effectual means for protecting the delicate anterior surface of the eye, for, when particles of dust approach it, they at once close, almost involuntarily. They shut also when the eye is exposed to a strong and injurious light. They are kept constantly closed during sleep; partly for the purpose of shutting off the rays of light, and partly also in order that the eye may be protected during this period of unconsciousness.

As it is necessary that the front of the eye-ball should be kept constantly moist, a special secretion is provided for this purpose. This secretion constitutes the Tears. The gland in which the tears are formed, called the Lachrymal Gland, 4, is placed at the upper and outer part of the orbit.¹ From it a number of small ducts proceed, which open on the inner surface of the upper lid. Through these ducts the tears are continually flowing; in ordinary states, in small quantities only. By the oft repeated winking movement of the upper eye-lid, the tears are conveyed across the front of the eye-ball so as to moisten it. Certain special channels are provided for carrying away this secretion after it has fulfilled its purpose. If the inner extremity of each eye-lid be examined, a small aperture, 5, of sufficient size, however, to admit a fine hair, may be seen. This aperture leads into a fine tube or duct, the tear duct; one proceeding from each lid. The two ducts gradually converge, join and open into a pouch-like dilatation, called the tear sac, 7. This is lodged in a depression in the inner wall of the orbit. From it a duct, 8, proceeds, which opens into the nose.

The tears, after moistening the eye, collect in the groove between the margin of the lid and the front of the ball. By this groove they are conducted to the small openings in the lid.

¹ A portion of the eye-brow and upper margin of the orbit have here been cut away in order to afford a view of the lachrymal gland.

They enter these openings and then proceed along the tear duct into the sac, and so into the nose. When the tears are formed in large quantities, as in the act of crying, the small orifices are not of sufficient size to carry off the secretion. In these cases, it runs over the margin of the lower lid and down the cheeks.

Lying within the cavity of the orbit are several small muscles, which are connected to the outer coat of the eye-ball. They are for the purpose of moving it. Four of these muscles are called the straight muscles. They all arise from the back of the orbit. One is inserted into the outer side of the ball, 9; this moves the eye outwards. Another into the inner side, 10; this moves the eye inwards. A third is inserted into the upper surface, 11; this elevates the eye-ball. The fourth one into the lower surface, 12; this depresses it. By observing the movements of the eye-ball, it will be seen that, when the inner straight muscle of one eye, say the right, contracts, that eye is drawn inwards, but, at the same time, the outer straight muscle of the left eye contracts, so as to draw it outwards. The two inner or the two outer straight muscles of the two eyes cannot be made to act at the same time, except by a very strong effort of the will. When they do so, however, an artificial squint is produced.

Two other muscles lying in the orbit are also connected to the ball; these are called the oblique muscles, 13, 14. The determination of the action of these muscles is an act of considerable difficulty. Their most probable function, however, is to rotate the eye-ball in the antero-posterior direction around the axis of vision, so as to bring both eyes, at the same time, into co-ordination, upon a single object.

The movement of the various muscles of the eye-ball is regulated by the small nerves, Plate VII., 41.

The movements of the eye-ball are facilitated by the presence of a considerable quantity of fat in the orbit, which, acting as a soft, flexible cushion, enables the eye to move readily from side to side.

The Eye-Ball.—The eye is composed of several distinct coats

or coverings, which are for the purpose of protecting the delicate nervous structures contained in its interior. In addition, it also possesses some highly delicate lenticular or refracting structures, which modify considerably the direction of the rays of light as they pass to the retina.

The eye is irregularly spheroidal in shape, from which circumstance it has been called the eye-ball or globe.

If viewed in section, as in Figure 3, it presents segments of two spheres, of which the anterior one is smaller and more prominent than the posterior.

The convexity of these spheres is regulated by the outer covering of the eye, which consists of two structures, presenting very strong contrasts to each other in their appearance. The more posterior, called the Sclerotic coat, 15, is thick, opaque, and white. It constitutes, in fact, the white of the eye. It is not confined in its position, however, to that part of the eye-ball which can be seen between the lids, but it extends backwards so as to invest the entire posterior surface of the globe. It is composed of fibrous tissue. By its great strength and inelasticity, it protects most effectually the back of the globe, and gives to it a permanent shape; the latter being a very essential quality, when it is remembered, how necessary it is, that the delicate internal lenticular organs should preserve their proper form.

The more anterior part of the external coat is the Cornea, 16. It constitutes the beautiful transparent structure at the front of the ball, through which all the rays of light proceed in their passage backwards to the retina. It is firmly connected by its circumference to the sclerotic. Although perfectly transparent, it yet possesses considerable strength and thickness. It is thus capable of effectually preserving the proper convexity of its light-transmitting surface.

Immediately within the sclerotic, lying next to it, and extending almost as far forwards, is the Choroid Coat, 17.

This coat is comparatively thin and delicate. It is of a deep black colour. It owes its colour to the presence of a large quan-

tity of pigment. In addition, it contains a number of blood-vessels, both arteries and veins, which enter the eye-ball at the posterior part. They pass through the sclerotic coat and run forwards in the choroid for the purpose of conveying blood to the different structures.

The choroid terminates in front in a number of finger-like processes, called the Ciliary Processes, 18.

Connected to the outer surface of these processes are a number of fine fibres which are undoubtedly muscular in their nature. They arise at the line of junction of the sclerotic, cornea, and iris, and pass backwards, to be connected to the ciliary processes. The name of Ciliary muscle is given to these fibres, 19.

Immediately within the choroid, and extending as far forwards as the ciliary processes, is the Retina, 20. This highly delicate and important membrane is formed partly of an expansion of the filaments of the optic nerve, 21, and partly of certain special structures which are peculiar to it. It occupies the posterior part of the globe. The surface, presented to the light, is concave. Its concavity is preserved by the peculiar structure called the vitreous body, to be afterwards described. It is perfectly transparent during life. The optic nerve enters the eye-ball at the posterior part, not quite in the axis, but a little to the inner side. It passes through the sclerotic and choroid coats, and then its filaments separate from each other and diverge in order to assist in forming the retina.

Fig. 4 represents a view of the inner surface of the retina. 21 is the point of entrance of the optic nerve, from this the fibres all diverge towards the margin of the retina.

The peculiar structures found in the retina are represented in Fig. 5, magnified many hundreds of times. These are extremely minute microscopic objects. They are rod-like in their general shape, and may be called the rods of the retina. They are placed in the retina, with their long axes forming almost a right angle with the long axes of the filaments of the optic nerve.

Their inner ends, 22, look towards the light, and project in

the narrow spaces between the filaments of the optic nerve. Their outer ends, 23, are in close contact with the inner surface of the choroid coat. They present one or two dilatations in their course, which are probably somewhat like, in their structure, the cells in a nerve centre.

Connected to one of these dilatations, generally to the innermost one, is a Nerve Cell, 24. The connection being established through the pole of the cell passing to the dilatation. Connected to another pole of the cell is a filament, 25, of the optic nerve. For all the filaments of this nerve must be considered as terminating through the medium of nerve cells in the rods of the retina. At one part of the retina, *i. e.*, exactly in the axis of vision, there are no optic nerve filaments; only the rods existing there. This spot, from its yellow colour, is called the Yellow Spot, 26.

Placed immediately behind the cornea is a chamber or cavity containing a watery fluid, the Aqueous Humour, 27.

Lying suspended in this chamber is the contractile muscular curtain, the Iris, 28. The Iris is a circular, ring-like body, attached by its circumference to the line of junction of the sclerotic and cornea. It is perforated in the centre by an aperture, the Pupil, 29.

The iris contains involuntary muscular fibres. Some of these surround the margin of the pupil; when they contract, they diminish the size of the aperture. Their contraction takes place whenever the pupil is exposed to a strong light, so that an excessive quantity of light is prevented passing backwards to the retina.

These changes in the iris take place involuntarily, and are examples of reflex action. For the stimulus of excessive light being conducted to the brain by the optic nerve, is reflected there through the agency of the nerve cells to the filaments of the motor nerve proceeding to the iris. These motor filaments induce, in the muscular fibres of the iris, that contraction which produces a *diminution* of the aperture of the pupil.

The other fibres are situated nearer the circumference of the iris; they have exactly the opposite action, for they dilate the pupil, so as to increase the size of the opening.

Dilatation of the pupil takes place when the light is feeble, and thus a greater number of rays are permitted to reach the retina. The muscularity of the iris is thus for the purpose of regulating the passage of the rays of light. The fluid in which it lies readily permitting its contractions to take place.

The colour of the iris varies in different eyes; in some it is blue, in others grey, in others dark brown or hazel. It depends upon the presence of pigment, which, by rendering the iris opaque, prevents the transmission of rays of light through it.

Directly behind the iris and pupil is the Crystalline Lens, 30. This is a double convex lens. The posterior surface is more convex than the anterior. It is a beautifully clear and transparent structure. It readily allows the rays of light to pass through, and it refracts them considerably in their passage.

Prolonged for a short distance on to the front of the lens is a fine membrane which is connected behind to the ciliary processes. Through this connection the lens is brought under the action of the ciliary muscle in a manner which will be afterwards more fully explained. The back of the lens is lodged in a depression in the front of a delicate structure which, from its glass-like transparency, is called the Vitreous Body or Humour, 31. This fills up the great bulk of the posterior part of the globe. It gives to the retina its concave shape, for its outer surface is in contact with the inner surface of that membrane. The ciliary processes are lodged in depressions at its anterior part, as at 32 in the fig.

Passage of the Visual Rays.—From the explanation that has now been given of Fig. 3, it will be seen that, situated in the axis of the eye-ball, are a number of transparent structures, through which the rays of light must all pass before they can reach the retina.

These are the cornea, aqueous humour, crystalline lens, and

vitreous body. Owing to the various degrees of convexity and density of these different media, the direction of the rays is considerably modified in their passage through them.

By the aid of Fig. 6, this may be explained. Let A B represent an object, from the extremities of which visual rays are emitted. These reach the cornea C, pass through it, and are refracted by it and the aqueous humour ; the refraction taking place towards the axis of the ray of light. The rays now enter the lens D, and are again refracted still more towards the centre ray. As they pass out of the lens into the vitreous humour E, they are again refracted, so that the rays finally meet at the points F and G, on the retina H, so as to produce at each of those spots a perfect image. The iris I, prevents rays passing through the circumference of the lens, which would be refracted differently from those proceeding through the centre ; the pigment, in its structure, absorbing all those rays which, by being transmitted through the outer part of the cornea, impinge upon it. The dilatation and contraction of this curtain permit, however, a greater or less number of rays to pass through the pupil, according to the vividness of the light or the condition of the eye itself.

It will be observed, that the rays from the opposite extremities of the object cross each other ; so that the rays proceeding from the lower end pass to the upper part of the retina, those from the upper end to the lower part. Hence the image on the retina is inverted. This may be readily seen, by taking the fresh eye of a sheep, and removing the sclerotic and choroid coats from the back of the eye-ball, when the image of any bright object, held before the cornea, will be observed in the inverted position. The solution of the question, as to why images, which appear inverted on the retina, are yet perceived by the mind in the erect position, is one of the most difficult problems connected with the physiology of vision ; and it cannot be said, that any satisfactory explanation has been afforded of it. The perfection of the image is owing to the different rays coming to a

common point or focus on the retina. If they do not do this, but converge either in front of or behind the retina, then the image is confused and indistinct.

Adaptation of the Eye to Distance.—As the bodies from which the rays of light proceed, are situated at varying distances from the retina; and as the rays which proceed from them, strike the cornea at angles varying with the distance of the object, it is necessary that the eye-ball should be provided with certain structures, which may so affect the varying angles of the visual rays, that they may all fall on the same focus in the retina. It is by means of these structures, that the eye is enabled to adapt itself to the vision of near and distant objects. There have been great differences of opinion, at various times, amongst anatomists, as to the structures by which this adaptation is effected. Some supposed that it was due to a change in the convexity of the cornea; others, to the lens being muscular, and producing, by the contraction of its fibre, changes in its curvature.

The most recent investigations into this subject show, that, whenever the eye is adapted to view a near object, a change takes place in the curvature of the anterior surface of the lens, by which it becomes more convex. This is produced through the combined action of the iris and ciliary muscle.

A necessary preliminary, is the contraction of the fibres that surround the margin of the pupil. This always takes place in looking closely at an object, so that the pupil becomes contracted. At the same time, the fibres of the ciliary muscle contract, so as to fix the ciliary processes and the point of attachment of the dilator fibres of the iris. By this means, the iris, which, under ordinary conditions, is curved, becomes straighter, and thus presses upon the anterior surface of the margin of the lens, which lies directly behind it. Now, as the lens cannot be pushed backwards, and as its substance is, to a certain extent, elastic, a change is produced in the curvature of the anterior surface, which projects towards the pupillary aperture, so as to *become more convex*.

The experiment which proves this change in the anterior surface of the lens to take place, is a very ingenious one. If a candle is held at some distance from the cornea of a person, three images may be observed to be reflected from the transparent media of the eye—one from the cornea, a second from the anterior surface, the third from the posterior surface of the lens. If the candle is now brought much closer to the cornea, the second image is observed to move forwards, so as to come nearer to the first one. This can only be owing to the increase in the curvature of the anterior surface of the lens.

The contraction of the iris, so as to produce a diminution in the size of the pupil, has already been mentioned as one of the necessary accompaniments of looking at a near object. The contrary always occurs—namely, dilatation of the pupil—when a distant object is being looked at. This not merely allows the curvature of the lens to assume its former condition, but it also enables a much greater number of rays of light to fall upon the retina.

Some individuals do not possess the power of adapting the eye to different distances. Of these, some can only see distinctly objects placed at a considerable distance. These are long-sighted persons. Others, again, can only see distinctly objects placed very near to the eye: these are short-sighted. When a long-sighted person looks at a near object, the rays of light meet, not on the retina, but behind it, so that a very indistinct image is produced. To remedy this, spectacles with convex glasses, must be employed; for there the rays will be brought sooner to a focus, so that they will fall upon the retina, and thus produce a perfect image. When a short-sighted person looks at a distant object, the rays of light meet in front of the retina, instead of upon it. By the use of spectacles, with concave glasses, the convergence of the rays is prevented, until they reach the retina, so as to produce there a perfect image.

Action of Light upon the Retina.—When rays of light fall upon the retina, they induce nerve currents, which, being con-

ducted along the filaments of the optic nerve to the part of the brain in which those filaments terminate, induce there a sensation of light. The rod-like bodies are the instrumental media through which the external light produces the current. The connection of these bodies to the optic nerve filaments, through the intervention of the nerve cells, explains the mode of passage of the current from the rod-like bodies to the nerve filaments, which are simply to be regarded as conductors of nerve force, and perfectly incapable of being primarily excited by external light. This is proved by the circumstance, that, at the part of the retina where the optic nerve enters, and where there are only filaments of this nerve, vision is incapable of being induced. The yellow spot, which is the part of the retina in which visual impressions are most readily excited, contains no optic nerve filaments, but is formed exclusively of the rod-like bodies. The yellow spot is situated exactly in the axis of the eye, or the axis of vision; so that it is the site of the most perfect vision.

In looking at an object, slight movements of the eye-ball, through the agency of the muscles, are constantly going on, so as to bring the various parts of that object in succession into the axis of vision.

It is probable that, to some extent at least, our ideas of the shape of an object are derived from the image on the retina corresponding in its form to that of the object looked at. Our idea of size is also, it is probable, to some extent dependent upon the relative size of the retina brought under the influence of the rays of light proceeding from the object. In estimating, however, both shape and size, we derive great assistance from the experience which has been afforded us by the education of the eye to the observation of different objects; for our ideas of the shape of a complex figure require that there should be something more than the image of that figure impressed on the retina. An effort of the mind is necessary, in order to determine the connection that the various lines bear to each other, so as to obtain a *just conception* of their proper relations. If we can call to the

sense of sight the assistance, at the same time, of touch, a much more clear and perfect idea is arrived at.

The motion of an object is determined by the movement of its image over the surface of the retina, and also by the movement of our own eyes which follow it.

An impression made upon the retina by any luminous object, remains for a short period of time, even after the object has been taken away. The duration of this impression depends, to some extent, upon the brightness of the object, but more especially on the length of time that the eye has been fixed upon it, and the degree of attention bestowed upon it. This is shown by the simple experiment, of twirling rapidly round a piece of lighted stick or string, when the impression produced upon any point of the retina remains until the object has reached the same point again, so that the idea of a luminous circle is conceived.

CHAPTER XXIII.

THE EAR AND THE SENSE OF HEARING.

THE Ear is the organ placed at the side of the head to which the atmospheric vibrations that produce sound are transmitted, and in which certain changes are produced, which, when conducted along the auditory nerve, result in the perception of sound by the mind. Like the eye, the ear is a complex structure; for there is to be considered, in connection with it, not merely the arrangement of the filaments of the Auditory nerve, but also certain accessory structures which assist in the transmission of auditory vibrations.

Divisions of the Ear.—Anatomists are in the habit of dividing the ear into three parts—the outer, middle, and inner ear.

The outer ear, called the *Auricle*, Fig. 9, 33, is placed on the exterior of the side of the head, being in close relation to the

bone of the temple. It is composed of cartilage, over which the skin is tightly stretched. The most depending part of the auricle, called Lobule, 34, does not contain any cartilage, but consists of a fold of the skin enclosing fat.

The outer surface of the auricle presents an irregular appearance owing to the presence of several elevations and depressions. The most considerable of these depressions has opening into it a canal, which, if traced inwards, is found to enter the temporal bone. The canal is called the External Auditory Meatus or Passage, 35. It is a little more than an inch in length. It is closed up at its inner end by a tight membrane stretched across it, called the Membrane of the Tympanum, 36.

At the orifice of the canal, where it opens into the auricle, a number of hairs are always found growing. The skin is prolonged down the passage, so as to line it.

If this part of the skin be examined, it is seen to present a number of small orifices, which lead into depressions in its substance. These depressions are small glands, and in them is secreted that peculiar waxy matter called Cerumen, which is always found in the auditory passage. If the ear wax is not removed by washing or other means, it is apt to collect in considerable quantities. It then obstructs the ear passage, and is a frequent cause of temporary deafness. The hairs at the entrance of the meatus and the peculiar secretion of its walls, prevent insects or other obnoxious objects from reaching the membrane of the tympanum.

Situated on the other side of the membrane of the tympanum is the cavity of the tympanum or drum of the ear, constituting the Middle Ear, 37. This cavity is separated by the membrane from the external auditory passage. It is a small box-like space walled in on every side. It communicates, however, with the back of the nose through a long tube, the Eustachian Tube, 38.

Along this tube air passes from the nasal passage into the tympanum; the mucous membrane lining the nose is also *prolonged into it*. A knowledge of this fact enables us to explain

how it is that temporary and partial deafness is so often produced when a person suffers from a severe cold in the nose. The membrane becomes swollen, and prevents the proper passage of the air into the tympanic cavity. At the inner wall of the tympanum are two openings in the bone, through which the tympanum would communicate with the internal ear if it were not that fine membranes are stretched across them.

Situated within the tympanum are three small bones, which possess very peculiar shapes—Fig. 10, magnified several times. They are called the Hammer, 39; the Anvil, 40; and the Stirrup, 41. They are articulated to each other by means of small joints. The hammer is connected by its handle to the membrane of the tympanum. The stirrup is connected by its broad end to the membrane filling up the oval opening in the inner wall of the tympanum that would have led into the vestibule. The anvil is connected on the one hand to the hammer, and on the other to the stirrup. These bones thus constitute a moveable chain stretching across the tympanum from the outer to the inner wall. Some small muscles are connected to them; one of the most important of these is called the tightener of the tympanum, 42.

This muscle is inserted into the handle of the hammer, and when it pulls upon it, it tightens the membrane of the tympanum.

The Inner Ear is a highly complex structure. From this circumstance it is called the Labyrinth, 43. Both it and the tympanum are situated in a very hard part of the temporal bone, which, from its almost stony hardness, is called the petrous portion of this bone.

The Labyrinth is divided into three parts: the Vestibule, 44; Semicircular Canals, 45; and Cochlea, 46, Fig. 11. In this figure they have been considerably enlarged in order more clearly to represent them. The Vestibule is a very small cavity placed internal to the inner wall of the tympanum, an oval opening existing in this wall, which is filled up by the membrane already described as having the base of the stirrup bone attached to it. The Semicircular Canals are three small curved canals opening

into the back of the vestibule. A fine membrane, corresponding exactly in shape to the vestibule and the canals, is contained in their interior. Within this membrane several small chalky deposits, called otolithes, 47, are found. The nerve of hearing, auditory nerve, sends a large branch to these parts, the terminations of the filaments becoming closely connected to these otolithes. Placed within this membrane, and also lying between it and the bony cavities in which it lies, is a small quantity of fluid.

The Cochlea is placed in front of the vestibule. It is a small spiral canal in the bone, forming two and a half turns. It closely corresponds in its shape to the shell of the common snail. It is represented in Fig. 12, several times enlarged, with the outer wall removed, so as to show the interior.

The canal of the cochlea is divided into two smaller canals by a thin spiral lamina, 48, extending its whole length. These canals communicate with each other at the apex of the cochlea, 49. At the base of the cochlea one of the canals opens into the front of the vestibule, so that the fluid in the vestibule becomes continuous with the fluid in the interior of the cochlea. The other canal would communicate with the tympanum by the round opening in its inner wall if it were not that a membrane stretched across prevented it. The spiral lamina of the cochlea possesses great importance, because upon it the filaments of the second division of the auditory nerve, 50, are distributed. These filaments are connected to bodies quite as peculiar in their structure as the rods already described in the retina. They differ from them, however, in shape and arrangement. They are called, after their discoverer, the rods of Corti. These peculiar rods are excited by the action of auditory vibrations, and, through their connection with the filaments of the nerve of hearing, certain changes in the nerve force are induced in those filaments, which, being conducted to the brain, produce the perception of sound. It must be remembered that the auditory nerve, like the optic, is *a mere conductor* of nerve force; and that, in order to induce

the currents along these nerves for the production of their special sensations by the natural stimulus, it is necessary that the induction take place through the peculiar structures connected with them. For the nerve of sight, the rods of the retina. For the nerve of hearing, the rods of Corti and their peculiar terminations in the vestibule.

Function of the External Ear.—The peculiar shape of the auricle is for the purpose of collecting the atmospheric vibrations, and transmitting them along the external meatus which opens into it. The uses of this structure are especially shown in those animals who possess the power of erecting this part of the ear, and turning its cavity in the direction from which sound is proceeding in order more clearly to define it. The vibrations now pass down the external meatus, and impinge at the bottom of this canal upon the membrane of the tympanum. The walls of this passage also exercise a considerable influence on the conduction of sound.

Functions of the Tympanum.—The membrane of the tympanum is by this means caused to vibrate, and the vibrations are propagated along the chain of bones to the oval membrane which separates the vestibule from the tympanum. These vibrations are permitted in the membrane owing to the compressibility of the air contained within the cavity of the tympanum allowing the necessarily small amount of movement to take place. Through the same cause also, the air by which the small bones are surrounded also permits their movements.

The presence of air within the tympanum thus becomes a matter of very great importance, not merely by allowing the vibrations of the membrane and the chain of bones readily to take place, but also by producing an equalization of the pressure upon the inner as well as the outer surface of the membrane. The air enters the tympanum along the Eustachian tube, so that all animals that possess a tympanum also possess an Eustachian tube. If this tube becomes obstructed by any means, then the acuteness of hearing is considerably diminished. It has already been mentioned, that the hammer-shaped bone which is con-

nected to the membrane of the tympanum, has a muscle inserted into it, the contraction of which produces tension of the membrane. Experience shows, that all loud noises, such as the report of a cannon, are very disagreeable, and at times even painful. If the membrane of the tympanum is made very tight, the vibrations cannot be so readily excited in it, so that sound is not so easily propagated to the labyrinth, and its intensity is consequently diminished. It is supposed that the tensor of the tympanum is put into action whenever the ear is exposed to loud noises, so that by tightening the membrane it may assist in lessening the intensity of the sound.

Functions of the Labyrinth.—Through the agency of the chain of bones and the oval membrane, the vibrations are propagated to the oval membrane and the vestibule. They excite vibrations in the fluid of the vestibule and semicircular canals, which act upon the terminations of the auditory nerves in the membrane lying in these two divisions of the labyrinth. At the same time, through the communication between the cochlea and the vestibule, the fluid in the cochlea is caused to vibrate, which, of course, influences the nerves distributed on its spiral lamina. In considering the action of vibrations upon the nerves in the cochlea, it must be remembered that one of its small canals is brought into relation with the tympanum through the membrane stretched across the round opening on its inner wall. Now, although the great majority of the vibrations of the membrane of the tympanum are directly propagated by the chain of bones to the vestibule, yet a few are, without doubt, communicated directly to the air within the cavity of the tympanum. These are transmitted across the cavity to the membrane filling up the round opening, which of necessity excites vibrations in the fluid of the cochlea. These must influence the nerves distributed upon its spiral lamina.

Through the arrangements that have now been described, it will have been perceived that all the vibrations which affect the *nerve of hearing*, impinge upon it through the medium of a fluid.

The tympanum, and the passage leading downwards to it, are not, however, the only channels along which auditory impressions may be conducted. The bones of the head are capable of doing this; and the extremely dense nature of that portion of the temporal bone in which the labyrinth is situated, greatly facilitates the transmission of these impressions to it.

It is extremely probable that the three divisions of the labyrinth fulfil different purposes; that the vestibule has for its object the determination simply of sound, of mere noise; the semicircular canals, again, determining the direction from which that sound proceeds. The cochlea, from the complexity of its structure, being the organ by which variations and degrees of sound are appreciated, as in the determination of musical notes or harmony. The varying power of appreciating music, in different persons, depending, perhaps, upon a more or less complete development of the peculiar structures with which the cochlear nerves are connected at their extremities.

CHAPTER XXIV.

THE NOSE AND THE SENSE OF SMELL.

SITUATED within the cavity of the Nose are the two nerves called Olfactory, which convey to the brain the nerve currents which induce the sense of smell in the part in which they terminate.

The nose is the prominent organ placed in front of the face, below and between the two eyes. It is placed above the mouth, and as it were guards that orifice, so that the odours of all substances put into the mouth are perceived through its agency.

In considering the anatomy of the nose, it must be remembered that it is a double organ, in the same sense as the eyes or ears are double. It is divided into two parts or nostrils, by a vertical partition called the septum of the nose, Fig. 15, 51.

Each nostril is complete in itself. Each nostril opens in front on the face, and behind into the pharynx.

The anterior openings of the nostrils are surrounded by cartilaginous plates, and the partition which separates one orifice from the other is also composed of cartilage. The outer wall of each nostril presents an irregular appearance, owing to the peculiar shape of the turbinated bones, which, as will be seen from Fig. 16, 52, are turned upon themselves. Between these bones are certain channels called the meatuses of the nose, 53. These meatuses communicate by orifices with the sinus in the frontal bone, 54, and with corresponding cavities in the interior of the ethmoid sphenoid bones and upper jaw bones. Into the lowest of the meatuses the tube leading downwards from the tear sac opens. The communications between the sinuses and the nasal cavity have induced some physiologists to suppose that they are subsidiary to the sense of smell. It is probable, however, that this is not the case, and that they are simply cavities in the bones of the head containing air, for the purpose of rendering them lighter than they would have been if they had been solid.

The septum of the nose, 51, completely separates one nostril from the other. It is vertical in its direction, and extends from the roof of the nose to the floor. Its surfaces consequently constitute the inner wall of each nostril.

The nose is lined throughout by a moist mucous membrane, which is prolonged through the openings in the meatuses into the cavities or sinuses existing in the above mentioned bones of the skull. This membrane is continuous posteriorly with the mucous membrane of the pharynx, whilst at the anterior nostril it becomes continuous with the skin of the face.

Beneath the mucous membrane in each nostril, both on the outer wall and also on the septum, the filaments of its own olfactory nerve are distributed, 55. These filaments do not extend beneath the entire substance of this membrane, but are confined in their distribution to the upper third of the nose. *They are connected to peculiar structures which appear to cor-*

respond to the rods already described in connection with the extremities of the optic and auditory nerves ; for by their agency are induced, in the olfactory nerve filaments, those currents which produce, in the part of the brain in which they terminate, the sense of smell.

The sense of smell is excited by odorous emanations from substances which, suspended in the atmosphere, enter the nostril, and there influence the olfactory nerves. One condition most essential to the excitation of this sense is, that the odorous particles should be capable of being dissolved in the mucus secreted by the membrane of the nose. It is owing to this circumstance that the sense of smell is always either impaired or temporarily lost in a person suffering from an attack of catarrh or common cold. In the first stage of this affection, the membrane is dry, owing to its secretion being no longer formed, so that the odorous exhalations are incapable of being dissolved. In the subsequent stage, the cavity of the nose becomes filled with the abundant secretion of the membrane, so that the odorous particles never reach it.

The intensity of this sense is heightened by making rapid and frequent inspirations through the nose, so as to bring successive portions of these particles into relation with the filaments of the olfactory nerve. The limitation of the distribution of the nerve to the upper part of the nose ensures a certain amount of warmth being communicated to the inspired air before it reaches the filaments, a circumstance which appears to facilitate the induction of the sense of smell.

GENERAL RELATIONS OF THE SENSES.

The various senses that have now been described, vary in intensity very much in different persons. This appears to a great extent to depend upon the degree in which any particular sense has been cultivated. The habit and modes of life of the individual thus influence materially the degree of perfection ex-

hibited by the sense. Those accustomed to live in the open air and in the country have, as a rule, the senses of sight, hearing, and smell, much more acute than those living in confined spaces in large cities. Men living a wild and savage life, possess these faculties to a very great extent, and they are enabled to discern the presence of an object at distances far exceeding those which one not accustomed to that mode of life can perceive.

In a similar manner, a sailor can discern a ship and make out the nature of her rigging, when a landsman is unable to see anything on the horizon, or perhaps but a mere speck.

The influence of education, as a means of perfecting the sense of sight, is very well exhibited in the use of the microscope. Those accustomed to work with that instrument, and who have consequently acquired an acquaintance, more or less familiar, with the various objects usually brought under its influence, being enabled to see the structure of any one of these objects much more readily than those who are unaccustomed to its use. The perception of the sensation peculiar to each particular organ is induced in that portion of the great sensory ganglia, at the base of the brain, in which the nerve proceeding from the organ terminates. The place of termination of the nerve must thus be regarded as the special seat of the sensation, and it is there that mere odour, light, sound, taste, or touch, are perceived.

Where a more complex idea of the nature of an object is required to be formed than can result from the mere perception of any of these qualities, then a distinct effort of the mind must be brought to bear upon it. This can be effected through the connection that exists between the sensory ganglia and the convolutions by the intervening white fibres. A very curious relation is to be observed between the senses, by means of which, if one is greatly impaired or altogether lost, the others become more acute, so as to supply, to some extent at least, the place of the injured one. This without doubt depends upon the individual being compelled to exercise or educate his other senses, in order *to make up for* the want of the lost one. In the blind, the

senses of hearing and touch become extremely acute, so that a blind person can distinguish different individuals by most minute differences in their tones of voice, or shape of the features.

RELATIONS OF THE OPENINGS INTO THE PHARYNX.

In Fig. 15 we have a vertical section through the cavities of the nose, mouth, larynx, and pharynx, by means of which we may be enabled to obtain a general idea of the relations of these parts to each other. The pharynx, 56, is observed to reach upwards as far as the under surface of the base of the skull. Opening into its upper part are the nostrils, 57, at the posterior part of which the orifice of the Eustachian tube, 58, may be seen. Below this is the opening of the back of the mouth, at the side of which is the tonsil, 59, lying in the hollow between the two arches of the palate.

Between the nostrils and the mouth is the soft palate, 60. Below the mouth the pharynx leads downwards into the esophagus, 61. It also communicates with the larynx, 62, through its upper orifice, 63; this opening being guarded by the valve-like epiglottis, 64.

Knowing the respective relations of these openings, we are enabled to understand how it is that air inspired through the nose or mouth passes down the larynx and trachea into the lungs. The distance of the opening of the larynx from the external openings of the above cavities, together with the length of the windpipe, enables the air to become both warm and moist before it reaches the delicate tissue of the lungs. During respiration the epiglottis is always elevated in order to allow the upward and downward movement of the air. Through the opening of the Eustachian tube into the nose, we can also understand how the air passes along it into the cavity of the tympanum. From the opening of the mouth into the pharynx, we perceive how it is that food, after leaving the mouth, passes down the pharynx into the esophagus and stomach during the act of swallow-

lowing ; the elevation of the soft palate so as to bring it in contact with the pharynx, preventing its passage upwards into the nose ; the depression of the epiglottis not allowing its passage downwards into the larynx.

CHAPTER XXV.

THE ORGAN OF VOICE.

THE organ of voice is situated in that portion of the windpipe to which the name of Larynx has been given. The larynx communicates below with the trachea, whilst above it opens into the pharynx.

Structure of the Larynx.—Its walls are formed of certain cartilaginous structures which enclose and protect the vocal cords, by the vibration of which the different tones of the voice are produced ; they also afford points of attachment for the muscles that act upon the vocal cords.

Of these cartilages the largest is the shield-like or Thyroid cartilage, Figs. 13 and 14, 65. It lies at the front of the larynx, and constitutes that prominence in the front of the neck of men, which is known by the name of the Pomum Adami, or Adam's Apple. It is not so prominent in women and children. The sides of this cartilage pass backwards, so as to protect the interior of the cavity of the larynx.

In Fig. 13 the outer surface of this cartilage is seen. Fig. 14 is a view of the larynx, looking into it from above. It is for the purpose of giving a representation of the relations of the most important of the cartilages to each other, of the connections of the vocal cords, and of the points of attachment of the various muscles that move them. Below the thyroid is a ring-like cartilage called the Cricoid, 66, which surrounds the larynx. *Upon the back of this cartilage, and at its upper margin, are*

situated two small cartilages called pitcher-like cartilages, or Arytenoid, 67. These are attached to the cricoid by a moveable joint, so that they readily move upon it. The great importance of these small cartilages consists in this circumstance, that to them are attached the vocal cords. The Vocal Cords are two in number, 68. They stretch across the larynx from the inner part of the front of the thyroid cartilage to the arytenoid cartilages. They are firmly connected at their extremities to these cartilages. They are covered by the mucous membrane of the larynx, and have connected to them certain muscles. Between the two is a chink or fissure, the fissure of the glottis, 69. The size of this varies very much at different times, and through it the air passes in its passage to or from the lungs. Connected to the inner surface of the thyroid cartilage is the valve-like epiglottis, 64, which is always elevated during respiration, so as to leave the upper orifice of the larynx open as this is going on. During deglutition, however, it is always depressed, in order to prevent the passage of any obnoxious material into the larynx.

The different cartilages above described move to a greater or less extent upon each other, through the intervention of distinct joints and synovial membranes. Thus the thyroid cartilage is articulated to the cricoid, and the cricoid to the arytenoid.

The muscles that move these cartilages upon each other are several. They are, with one exception, arranged in pairs, corresponding muscles being found on each side of the larynx. By their action, the vocal cords are either tightened or relaxed, and the fissure of the glottis is either diminished or increased in size. The names of these muscles express the parts to which they are connected. The largest is the Crico-thyroid, 70. It arises from the front of the cricoid, and passes backwards to be inserted into the lower margin of the thyroid cartilage.

The Posterior Crico-arytenoid, 71, arises from the back of the cricoid, and passes forwards to be inserted into the outer part of the arytenoid. The Lateral Crico-arytenoid, 72, arises from the side of the cricoid, and passes backwards to be inserted into the

outer surface of the arytenoid. The Thyro-arytenoid, 73, arises from the thyroid cartilage; its fibres pass backwards, parallel to the vocal cord, some to be inserted into it, others into the arytenoid cartilage itself. The above are in pairs, corresponding muscles existing on the two sides. The single muscle called Arytenoid, 74, extends between the two cartilages of that name.

With regard to the action of these muscles, they have been arranged in two classes, viz., those that regulate the aperture of the glottis, and those that affect the tension of the vocal cords.

To the first class belong the

Posterior Crico-arytenoid muscles, which, by rotating outwards the arytenoid cartilages, increase the opening of the glottis.

The Lateral Crico-arytenoid, which, by rotating the arytenoid cartilages inwards, diminish the aperture of the glottis.

The Arytenoid, which, by drawing the two arytenoid cartilages together, also diminishes the aperture of the glottis.

The muscles that affect the tension of the vocal cords are, the—

Crico-thyroid, which, by drawing the thyroid away from the arytenoid cartilages, tighten the vocal cords.

The Thyro-arytenoid, which, by approximating these cartilages, relax the vocal cords.

The Voice.—The sounds of the voice are produced by the air during expiration, which, passing through the chink of the glottis, throws into vibration the two vocal cords, between which it passes. As it is by the expired air that the voice is produced, it becomes necessary, during continued speaking, to renew the air in the cavity of the chest, by taking at intervals a full inspiration. The tension of the vocal cords, and the shape and size of the aperture of the glottis, influence materially the formation of the voice. It has been shown by experiment, that in order to produce the sounds of the voice, the vocal cords must be parallel to each other, so that the aperture becomes a simple slit. By the narrowing of this fissure during speaking, considerable *economy* is effected in the use of the expired air, for it can only *pass out slowly*, so that the voice may be prolonged for a com-

paratively lengthy period, without there being any necessity for taking an inspiration. In the ordinary conditions of the glottis, when the individual is not speaking, but merely breathing, the vocal cords are not parallel, but are farther apart at their posterior than at their anterior extremity. This permits a larger space for the air to pass through during respiration.

The pitch of the voice appears to be regulated by the tension of the cords. When a high note is produced, the cords are very tense; the opposite state, viz., that of relaxation, being the case when a low note is sounded. The notes intermediate between high and low are produced by an intermediate state of the cord, between great tension and extreme relaxation. It is in the power of the individual to produce these different modifications of sound. Thus, when a high note is wished to be sounded, by raising the head so as to stretch the neck, the larynx is raised at the same time, and the vocal cords put upon the stretch. When the opposite sound is desired, viz., the production of a low note, by the depression of the chin the larynx falls, and the vocal cords are slackened.

The structures described in connection with the larynx are quite sufficient for the production of sound, as in singing, from the highest treble to the deepest bass; but for the production of articulate sounds or speech, other structures are called into requisition. These are certain of the moveable organs contained in or about the mouth, viz., the soft palate, tongue, and lips. The movements of these exercise great influence upon the production of certain sounds, which we are in the habit of representing symbolically by the aid of letters. According as one or other of these structures preponderates in the formation of certain sounds, they are the symbols representing them spoken of by the initials, viz., palatal, labial, &c.

A disagreeable affection called stammering, in the majority of instances, upon the exercise perfect control over the organs in the production of speech. It is

always much worse when the person is labouring under any great emotion, because then the very slight control which, in tranquil moments even, he is enabled to place upon these muscles, becomes considerably diminished. Hence, in the treatment of this affection, the speech should be slow and deliberate; the mind, as much as possible, should be led away from the contemplation of the disorder; and especial care should be taken to avoid all mental emotion at the time of speaking.

The sense of hearing appears to exercise a great influence upon the production, not merely of the voice, but of those sounds by which speech is effected. A person with a quick and ready ear, and whose speech organs are properly formed, will much more readily acquire the power of forming a new sound, such as he may meet with in the acquisition of a foreign language, than one whose sense of hearing is not so acute or precise. Hence it happens that persons who are born deaf are at the same time dumb; for, as they have never heard the sound of any language, it is not possible that they can imitate them.

CHAPTER XXVI.

CONCLUSION.

IN the preceding pages, a sketch has been given of those structures and functions which minister to the growth and maintenance of the life of the individual, by which he increases in size, as in the passage from the state of infancy to that of adult life, and by which, after having arrived at the latter stage, his system is preserved in a condition adapted to the performance of its various duties. Those processes, the office of which is to assist in the reproduction and perpetuation of the species, will not here be considered.

It will have been seen, that for the performance of the numer-

ous functions different organs are set apart and peculiarly adapted, each fulfilling its own office in a highly perfect manner. One of the most essential characters by which man and the higher animals are distinguished from the lower types of organization, consists in this *differentiation* of the organs, as it has been termed ; that is, the setting apart of particular organs for particular purposes.

In the very lowest forms of life, the separation of the body into different organs does not occur. The whole substance of the animal appearing indifferently to perform the various functions required of it. But whilst we observe the differentiation of organ and function in those higher types of organization represented by man and the animals most closely allied to him, we must not forget that the different parts are mutually dependent upon each other. Hence it happens, that when disease or injury impairs the structure or functions of any particular part, the whole system, to a certain extent, suffers ; this being dependent upon the amount of injury that the organ has received, or its importance in the economy of the individual. Many of the organs most closely related to each other in their function appear to possess, however, a curious compensating influence, by which an impairment of the function of one is followed by an increase in the activity of the other. This is especially shown in the case of the skin, lungs, and kidneys. All these organs possess, as one of their functions, the power of excreting or separating water from the system. It has been found by observation, that when this is interfered with in one of these localities, the others put on an increased action. The duplicity of many of the organs is evidently for the purpose of enabling the functions performed by them to be carried on, should one be seriously injured. That this is the case, is shown by the circumstance, that if one is destroyed, an increase takes place in the size of the other. Over all the organs the nervous system exercises a controlling influence, so that it must be ranked as amongst the most important of them all.

In contemplating the adaptation of the different organs to the functions they are destined to perform, one cannot fail to admire the abundant indications of Design exhibited in the construction of the different parts; how they are all brought to bear upon one common end, viz., the preservation of the body in a state of health; and how, for this purpose, the mechanism and mode of action of each part is perfect in its nature.

But whilst there exists in the Economy a power by which it can renovate itself, so as to make good the waste that is constantly taking place in it in the exercise of its functions, yet there is a natural tendency in the tissues or organs to degenerate or decay after the lapse of some time. The period at which this may take place appears to vary greatly in different individuals, and to be, to a great degree, dependent upon the conditions by which the individual is surrounded. This degeneration may manifest itself in various ways, but especially in the two following:—The deposition of fat in certain organs, or parts of organs, so that the natural structure of the part becomes replaced by fatty materials. The withering or drying up of the parts, so that they become wasted and shrivelled; this form is generally seen in old persons.

In addition to the tendency to degeneration, which may be considered natural to the body, it suffers at various times from attacks of disease. These may be produced by the neglect of the individual, who, indulging in excess or errors of diet, or subjecting himself to noxious emanations, or failing to attend to personal cleanliness, induces disease in those parts of his body which are especially exposed to these different injurious influences. Numbers, however, of diseases appear to be produced, not so much by the neglect of individuals, as by communities failing entirely to look after the means of preserving health, or doing so in an inefficient manner. The crowding together of numbers of persons in confined localities, without providing methods by which the various emanations and excretions proceeding from them may be cleared away, is one of the most fruitful predisposing causes of disease;

especially of those epidemic disorders, which, raging like pestilences, carry dismay and death into numerous households.

That emanations from animal bodies are injurious to the health of other animals, appears to be a fact, about which, at this present time, there cannot be a doubt. The earth and the atmosphere are the great receptacles naturally provided for the diffusion and dispersion of these various disease-inducing influences. But whilst they exercise deleterious effects upon animal life, they are of the greatest value in promoting the growth and nutrition of plants, the food of which consists of those materials, that not merely cannot minister to, but absolutely produce an injurious influence upon the life of animals.

The two great divisions of the organized world thus bear a very curious relation to each other.

The animal evolves certain materials, which, either conveyed by the air or commingled with the soil, reach the plant, and are by it applied to the purpose of its nutrition. Through these means the plant develops and grows, and prepares those materials which, when taken as food by the animal, after digestion and absorption, can be applied to the nutrition of its tissues.

THE END.

